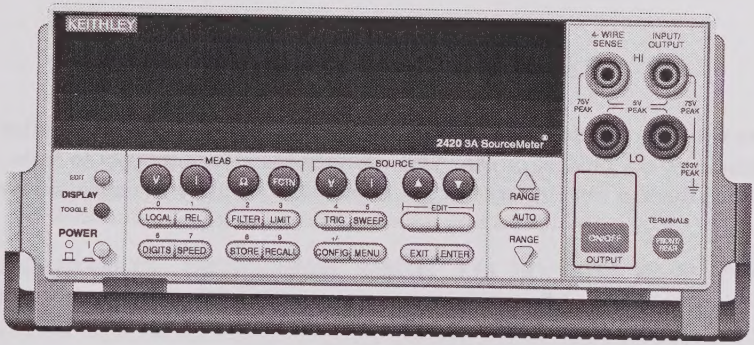
KEITHLEY

MP MASTER
MA36378

Model 2420
3A SourceMeter®

User's Manual



Contains Operating and Programming Information

KEITHLEY

WARRANTY

Keithley Instruments, Inc. warrants this product to be free from defects in material and workmanship for a period of 1 year from date of shipment.

Keithley Instruments, Inc. warrants the following items for 90 days from the date of shipment: probes, cables, rechargeable batteries, diskettes, and documentation.

During the warranty period, we will, at our option, either repair or replace any product that proves to be defective.

To exercise this warranty, write or call your local Keithley representative, or contact Keithley headquarters in Cleveland, Ohio. You will be given prompt assistance and return instructions. Send the product, transportation prepaid, to the indicated service facility. Repairs will be made and the product returned, transportation prepaid. Repaired or replaced products are warranted for the balance of the original warranty period, or at least 90 days.

LIMITATION OF WARRANTY

This warranty does not apply to defects resulting from product modification without Keithley's express written consent, or misuse of any product or part. This warranty also does not apply to fuses, software, non-rechargeable batteries, damage from battery leakage, or problems arising from normal wear or failure to follow instructions.

THIS WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR USE. THE REMEDIES PROVIDED HEREIN ARE BUYER'S SOLE AND EXCLUSIVE REMEDIES.

NEITHER KEITHLEY INSTRUMENTS, INC. NOR ANY OF ITS EMPLOYEES SHALL BE LIABLE FOR ANY DIRECT, INDIRECT, SPECIAL, INCIDENTAL OR CONSEQUENTIAL DAMAGES ARISING OUT OF THE USE OF ITS INSTRUMENTS AND SOFTWARE EVEN IF KEITHLEY INSTRUMENTS, INC., HAS BEEN ADVISED IN ADVANCE OF THE POSSIBILITY OF SUCH DAMAGES. SUCH EXCLUDED DAMAGES SHALL INCLUDE, BUT ARE NOT LIMITED TO: COSTS OF REMOVAL AND INSTALLATION, LOSSES SUSTAINED AS THE RESULT OF INJURY TO ANY PERSON, OR DAMAGE TO PROPERTY.

Model 2420 3A SourceMeter®
User's Manual

©1997, Keithley Instruments, Inc.
All rights reserved.
Cleveland, Ohio, U.S.A.
First Printing, April 1997
Document Number: 2420-900-01 Rev. A

Worldwide Addresses

Keithley Instruments, Inc.
28775 Aurora Road
Cleveland, OH 44139
440-248-0400
Fax: 440-248-6168
http://www.keithley.com

CHINA
Keithley Instruments China
Yuan Chen Xin Building, Room 705
12 Yumin Road, Dewai, Madian
Beijing 100029
8610-62022886
Fax: 8610-62022892

FRANCE
Keithley Instruments SARL
BP 60
3 Allée des Garays
91122 Palaiseau Cédex
33-1-60-11-51-55
Fax: 33-1-60-11-77-26

GERMANY
Keithley Instruments GmbH
Landsberger Strasse 65
D-82110 Germering, Munich
49-89-8493070
Fax: 49-89-84930759

GREAT BRITAIN
Keithley Instruments, Ltd.
The Minster
58 Portman Road
Reading, Berkshire
England RG3 1EA
44-1189-596469
Fax: 44-1189-575666

ITALY
Keithley Instruments SRL
Viale S. Gimignano 38
20146 Milano
39-2-48303008
Fax: 39-2-48302274

NETHERLANDS
Keithley Instruments BV
Avelingen West 49
4202 MS Gorinchem
31-(0)183-635333
Fax: 31-(0)183-630821

SWITZERLAND
Keithley Instruments SA
Kriesbachstrasse 4
8600 Dübendorf
41-1-8219444
Fax: 41-1-8203081

TAIWAN
Keithley Instruments Taiwan
1FL., 85 Po Ai Street
Hsinchu, Taiwan
886-3-572-9077
Fax: 886-3-572-9031

Manual Print History

The print history shown below lists the printing dates of all Revisions and Addenda created for this manual. The Revision Level letter increases alphabetically as the manual undergoes subsequent updates. Addenda, which are released between Revisions, contain important change information that the user should incorporate immediately into the manual. Addenda are numbered sequentially. When a new Revision is created, all Addenda associated with the previous Revision of the manual are incorporated into the new Revision of the manual. Each new Revision includes a revised copy of this print history page.

Revision A (Document Number 2420-900-01) ..... April 1997

All Keithley product names are trademarks or registered trademarks of Keithley Instruments, Inc.
Other brand names are trademarks or registered trademarks of their respective holders.

Safety Precautions

The following safety precautions should be observed before using this product and any associated instrumentation. Although some instruments and accessories would normally be used with non-hazardous voltages, there are situations where hazardous conditions may be present.

This product is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read the operating information carefully before using the product.

The types of product users are:

Responsible body is the individual or group responsible for the use and maintenance of equipment, and for ensuring that operators are adequately trained.

Operators use the product for its intended function. They must be trained in electrical safety procedures and proper use of the instrument. They must be protected from electric shock and contact with hazardous live circuits.

Maintenance personnel perform routine procedures on the product to keep it operating, for example, setting the line voltage or replacing consumable materials. Maintenance procedures are described in the manual. The procedures explicitly state if the operator may perform them. Otherwise, they should be performed only by service personnel.

Service personnel are trained to work on live circuits, and perform safe installations and repairs of products. Only properly trained service personnel may perform installation and service procedures.

Exercise extreme caution when a shock hazard is present. Lethal voltage may be present on cable connector jacks or test fixtures. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V RMS, 42.4V peak, or 60VDC are present. **A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.**

Users of this product must be protected from electric shock at all times. The responsible body must ensure that users are prevented access and/or insulated from every connection point. In some cases, connections must be exposed to potential human contact. Product users in these circumstances must be trained to protect themselves from the risk of electric shock. If the circuit is capable of operating at or above 1000 volts, **no conductive part of the circuit may be exposed.**

As described in the International Electrotechnical Commission (IEC) Standard IEC 664, digital multimeter measuring circuits (e.g., Keithley Models 175A, 199, 2000, 2001, 2002, and 2010) measuring circuits are Installation Category II. All other instruments' signal terminals are Installation Category I and must not be connected to mains.

Do not connect switching cards directly to unlimited power circuits. They are intended to be used with impedance limited sources. NEVER connect switching cards directly to AC mains. When connecting sources to switching cards, install protective devices to limit fault current and voltage to the card.

Before operating an instrument, make sure the line cord is connected to a properly grounded power receptacle. Inspect the connecting cables, test leads, and jumpers for possible wear, cracks, or breaks before each use.

For maximum safety, do not touch the product, test cables, or any other instruments while power is applied to the circuit under test. ALWAYS remove power from the entire test system and discharge any capacitors before: connecting or disconnecting cables or jumpers, installing or removing switching cards, or making internal changes, such as installing or removing jumpers.

Do not touch any object that could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface capable of withstanding the voltage being measured.

Do not exceed the maximum signal levels of the instruments and accessories, as defined in the specifications and operating information, and as shown on the instrument or test fixture panels, or switching card.

When fuses are used in a product, replace with same type and rating for continued protection against fire hazard.

Chassis connections must only be used as shield connections for measuring circuits, NOT as safety earth ground connections.

If you are using a test fixture, keep the lid closed while power is applied to the device under test. Safe operation requires the use of a lid interlock.

If a screw is present, connect it to safety earth ground using the wire recommended in the user documentation.

The symbol on an instrument indicates that the user should refer to the operating instructions located in the manual.

The symbol on an instrument shows that it can source or measure 1000 volts or more, including the combined effect of normal and common mode voltages. Use standard safety precautions to avoid personal contact with these voltages.

The **WARNING** heading in a manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading in a manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

Instrumentation and accessories shall not be connected to humans.

Before performing any maintenance, disconnect the line cord and all test cables.

To maintain protection from electric shock and fire, replacement components in mains circuits, including the power transformer, test leads, and input jacks, must be purchased from Keithley Instruments. Standard fuses, with applicable national safety approvals, may be used if the rating and type are the same. Other components that are not safety related may be purchased from other suppliers as long as they are equivalent to the original component. (Note that selected parts should be purchased only through Keithley Instruments to maintain accuracy and functionality of the product.) If you are unsure about the applicability of a replacement component, call a Keithley Instruments office for information.

To clean the instrument, use a damp cloth or mild, water based cleaner. Clean the exterior of the instrument only. Do not apply cleaner directly to the instrument or allow liquids to enter or spill on the instrument.

Table of Contents

1 General Information

Introduction....1-2
Feature overview....1-2
Warranty information....1-3
Manual addenda....1-3
Safety symbols and terms....1-3
Specifications....1-3
Inspection....1-4
Options and accessories....1-5
- General purpose probes....1-5
- Low thermal probes....1-5
- Cable and adapters....1-6
- Rack mount kits....1-6
- Carrying case....1-6

2 Basic Source-Measure Operations

Introduction....2-2
Warning-Caution....2-3
Source-measure concepts....2-4
- Operation overview....2-4
- Compliance limit....2-5
- Overheating protection....2-10
- Overheating prevention power equations....2-10
- Operating boundaries....2-11
- Recommended calibration equipment....2-13
- 1Ω resistor characterization....2-14
- Basic circuit configurations....2-18
- Data flow....2-28
- Buffer considerations....2-28

Front and rear panel familiarization....2-31
- Front panel summary....2-31
- Rear panel summary....2-31

Cooling fan....2-36
Display....2-36
- Edit key....2-36
- Toggle key....2-37
- Status and error messages....2-37

Rules to navigate menus....2-38
Connections....2-39
- Front/rear terminals selection....2-39
- Test fixture interlock....2-39
- Connections to DUT....2-40

Sense and guard selections 2-44
Basic source-measure procedure 2-45
Basic ohms measurement procedures 2-49
Selecting ohms measurement method 2-49
Auto ohms measurements 2-50
Manual ohms measurements 2-51
Offset-compensated Ω 2-52
Enabling/disabling offset-compensated ohms 2-52
Offset-compensated ohms procedure 2-53
Measure only (V or I) 2-53
Sink operation 2-54
Battery charging/discharging 2-55
Sweep operation 2-56
Sweep types 2-56
Select and configure sweep 2-61
Set delay 2-62
Perform sweep 2-62
Limit testing 2-63
Operation overview 2-64
Binning systems 2-67
Digital output clear pattern 2-70
Configure limit tests 2-72
Perform limit tests 2-73
Math (FCTN) operations 2-74
Power 2-74
Offset compensated Ω 2-74
Varistor alpha 2-75
Voltage coefficient 2-75
Percent deviation 2-75
Selecting and enabling math expression 2-76

3 Source-Measure Options

Introduction 3-2
Measurement configuration 3-3
Range 3-3
Filter 3-4
Relative 3-6
Digits 3-7
Speed 3-8
Source configuration 3-9
Configure V-source and I-source 3-9
Trigger operations 3-10
Trigger model 3-10
Trigger link 3-15
Configure triggering 3-20
Data store 3-21

Storing readings 3-21
Recalling readings 3-21
Digital I/O port and safety interlock 3-23
Configure output 3-25
Output Off States 3-25
Main menu 3-27

4 Troubleshooting

Introduction 4-2
Differences: remove vs. local operation 4-3
Operation enhancements (remote operation) 4-3
Local to remote transition 4-3
CHAR SET test 4-3
Remote to local transition 4-4
Selecting an interface 4-5
GPIB bus operation and reference 4-6
GPIB bus standards 4-6
GPIB bus connection 4-7
Primary address 4-8
QuickBASIC 4.5 programming 4-9
Universal program fragments 4-9
Using program fragments 4-9
General Bus Commands 4-10
Front panel aspects of GPIB operation 4-13
Status structure 4-15
Condition registers 4-15
Event registers 4-15
Enable registers 4-15
Queues 4-19
Status Byte and Service Request (SRQ) 4-23
Trigger model (remote operation) 4-23
Idle and initiate 4-24
Trigger model operation 4-24
Programming syntax 4-27
Command words 4-27
Program messages 4-30
Response messages 4-32
Message exchange protocol 4-33
Common commands 4-34
RS-232 operation 4-47
Sending and receiving data 4-47
Baud rate 4-47
Data Bits and Parity 4-47
Terminator 4-48
Flow control (signal handshaking) 4-48
RS-232 connections 4-49
Error messages 4-50

5 SCPI Command Reference

Introduction 5-2
SCPI signal measurement commands 5-3
Configure measurement function 5-3
Acquire readings 5-4
SCPI command subsystems 5-6
Reference tables 5-6
Calculate subsystems 5-20
CALCulate [1] 5-20
Assign unit suffix 5-24
Define math expression 5-25
Enable and read math expression result 5-28
CALCulate2 5-29
Select input path 5-29
Null fee reading 5-29
Read CALC2 5-30
Configure and control limit tests 5-30
Clear test results 5-34
CALCulate3 5-35
Select statistic 5-35
Aquire statistic 5-35
:DISPlay subsystem 5-37
Control display 5-37
Read display 5-38
Define :TEXT messages 5-39
FORMat subsystem 5-40
Data format 5-40
Data elements 5-43
Byte order 5-46
Status register format 5-46
OUTPut subsystem 5-47
Turn source on or off 5-47
Interlock control 5-47
Output-off states 5-47
:ROUTe subsystem 5-49
Select input jacks 5-49
SENSe1 subsystem 5-50
Select measurement functions 5-50
Select measurement range 5-51
Set compliance limit 5-55
Set measurement speed 5-56
Configure and control filter 5-56
SOURce subsystem 5-58
SOURce[1] 5-58

Control source output-off 5-58
Select function mode 5-58
Select sourcing mode 5-59
Select range 5-59
Select amplitude for fixed source 5-61
Set voltage limit 5-62
Set delay 5-63
Configure voltage and current sweeps 5-64
Configure list 5-68
Configure memory sweep 5-70
Sweep and list program examples 5-72
SOURce2 5-74
Setting digital output 5-75
Clearing digital output 5-75
STATus subsystem 5-77
Read event registers 5-77
Program event enable registers 5-80
Read condition registers 5-82
Select default conditions 5-83
Error queue 5-83
:SYSTem subsystem 5-86
Default conditions 5-86
Select input jacks 5-86
Control remote sensing 5-87
Select guard mode 5-87
Reset timestamp 5-88
Initialize memory 5-88
Cooling fan (output off) 5-88
Control beeper 5-89
Control autozero 5-89
Select power line frequency setting 5-90
Error queue 5-90
Simulate key presses 5-92
Read version of SCPI standard 5-93
RE-232 interface 5-94
:TRACe subsystem 5-95
Read and clear buffer 5-95
Configure and control buffer 5-95
Select timestamp format 5-97
Trigger subsystem 5-98
Initiate source/measure cycle 5-98
Abort source/measure cycle 5-98
Program trigger model 5-98

A Specifications

Accuracy calculations A-6
Measurement accuracy A-6
Source accuracy A-6
Source-Delay-Measure (SDM) cycle timing A-7
Definitions A-7

B Status and Error Messages

C Operating Examples

Introduction C-2
Basic sweep operation C-2
Sweep test example C-2
Sweep operation programming steps C-3
SRQ on sweep done C-5
SRQ on OPC C-5
SRQ on MAV C-5
SRQ on IDLE C-5
Pass/fail testing C-6
Pass/fail test example C-6
Pass/fail test programming steps C-7
Resistor voltage coefficient testing C-9
Resistor voltage coefficient test example C-9
Programming steps C-10
Example programs C-11
Computer hardware requirements C-11
Software requirements C-11
General program instructions C-11
Basic sweep operation program C-12
Limits testing program C-14
Voltage coefficient test program C-15

D Data Flow

Introduction D-2
FETCh? D-3
CALCulate[1]:DATA? D-3
CALCulte2:DATA? D-3
TRACeDATA? D-4
CALCulate3:DATA? D-4

E Factory Defaults

F IEE-488 Bus Overview

Introduction F-2
Bus description F-4
Bus lines F-5
Data lines F-6
Bus management lines F-6
Handshake lines F-7
Bus commands F-8
Uniline commands F-9
Universal multiline commands F-9
Addressed multiline commands F-10
Address commands F-10
Unaddress commands F-10
Common commands F-11
SCPI commands F-11
Command codes F-11
Typical command sequences F-13
IEEE command groups F-14
Interface function codes F-15

G IEEE-488 and SCPI Conformance Information

Introduction G-2

List of Illustrations

2 Calibration

Source-delay-measure (SDM) cycle 2-8
Three basic sweep waveform types 2-9
Operating boundaries 2-12
I-source boundaries 2-13
I-source operating examples 2-14
V-source boundaries 2-15
V-source operating examples 2-17
Fundamental source-measure configuration 2-18
Source I 2-19
Source V 2-20
Measure only (V or I) 2-21
High-impedance measurements 2-23
In-circuit ohms measurements 2-25
In-circuit ohms measurements using guard sense 2-27
Data flow-front panel 2-30
Model 2420 front panel 2-31
Model 2420 rear panel 2-33
Power module 2-35
Two-wire connections (local sense) 2-40
Four-wire connections (remote sense) 2-40
High-impedance guarding 2-42
Guarded ohms measurements 2-43
Linear staircase sweep 2-56
Logarithmic staircase sweep 2-58
Custom pulse sweep 2-59
Limit tests 2-63
Limits operation 2-65
Handler interface connections 2-67
Binning system-single element device 2-68
Binning system-multiple element devices 2-69
Digital output auto-clear timing example 2-70

3 Source-Measure Options

Moving average and repeating filters 3-5
Trigger model (front panel operation) 3-11
Rear panel pinout 3-15
Trigger link input pulse specifications 3-15
Trigger link output pulse specifications 3-16
DUT test system 3-16
Trigger link connection 3-17
Operation model for triggering example 3-18
Interlock and digital I/O port 3-23
Using test fixture interlock 3-24

4 Remote Operation

IEEE-488 connector 4-7
IEEE-488 connections 4-7
IEEE-488 connector location 4-8
Model 2420 status register structure 4-16
Standard event status 4-17
Operation event status 4-18
Measurement event status 4-18
Questionable event status 4-19
Status byte and service request (SRQ) 4-20
Trigger model (remote operation) 4-23
Device action (SDM cycle) 4-25
Standard event status register 4-39
Service request enable register 4-43
Status byte register 4-44
RS-232 interface connector 4-49

5 SCPI Command Reference

ASCII data forms 5-40
IEEE754 single precision data format (32 data bits) 5-41
Measurement event register 5-78
Questionable event register 5-78
Operation event register 5-78
Measurement event enable register 5-81
Questionable event enable register 5-81
Operation event enable register 5-81
Key-press codes 5-93

C Operating Examples

Connections for diode I-V tests C-3
Typical diode I-V curve C-3
Diode pass/fail limits C-7
Connections for voltage coefficient tests C-9
Sweep program example plot C-12

D Data Flow

Data flow block diagram D-2

F IEEE-488 Bus Overview

IEEE-488 bus configuration F-5
IEEE-488 handshake sequence F-7
Command codes F-12

List of Tables

4 Remote Operation

General bus commands and associated statements 4-10
IEEE-488.2 common commands and queries 4-34
RS-232 connector pinout 4-49
PC serial port pinout 4-50

5 SCPI Command Reference

Signal oriented measurement command summary 5-3
CALCulate command summary 5-7
DISPlay command summary 5-9
FORMat command summary 5-10
OUTput command summary 5-10
ROUTe command summary 5-10
SENSe command summary 5-11
SOURce command summary 5-13
STATus command summary 5-16
SYSTem command summary 5-17
TRACe command summary 5-18
Trigger command summary 5-19

B Status and Error Messages

Status and error messages B-2

C Operating Examples

Command sequence for basic sweep operation C-4
Command sequence for pass/fail tests C-8
Pass/fail test summary C-8
Voltage coefficient test commands C-10

F IEEE-488 Bus Overview

IEEE-488 bus command summary F-8
Hexadecimal and decimal command codes F-11
Typical addressed command sequence F-13
IEEE command groups F-14
Model 2420 interface function codes F-15

G IEEE-488 and SCPI Conformance Information

IEEE-488 documentation requirements G-2
Coupled commands G-4

1
General Information

Introduction

This section contains general information about the Model 2420 SourceMeter. The information is organized as follows:

- Feature overview
- Warranty information
- Manual addenda
- Safety symbols and terms
- Specifications
- Inspection
- Options and accessories

If you have any questions after reviewing this information, please contact your local Keithley representative or call one of our Applications Engineers at 1-800-348-3735 (U.S. and Canada only). Worldwide phone numbers are listed at the front of this manual.

Feature overview

The Model 2420 combines a precision, low-noise, highly stable DC power supply with a low-noise, highly repeatable, high-impedance multimeter. It has 0.012% basic accuracy with 5½-digit resolution. At 5½ digits, the SourceMeter delivers 520 readings/second over the IEEE-488 bus. At 4½ digits, it can read up to 2000 readings/second into its internal buffer. The Model 2420 has broad source and measurement ranges:

- Source voltage from 5μV to 63V; measure voltage from 1μV to 66V.
- Source current from 500pA to 3.15A; measure current from 100pA to 3.3A.
- Measure resistance from 10μΩ (<10μΩ in manual ohms) to 20MΩ.

Some additional capabilities of the Model 2420 include:

- Concurrent measurements of all three functions over the remote interface.
- Source-measure sweep capabilities (linear and logarithmic staircase sweeps, source sweep list of up to 1000 points, memory sweep of up to 100 instrument setups).
- 6-wire Ω measurement with programmable I-source or V-source with V or I clamp.
- 66W, 4-quadrant source and sink operation.
- Up to three stages of limit testing with a built-in comparator for pass/fail testing.
- Digital I/O for stand-alone binning operations or interface to component handler.
- Programming language and remote interfaces — The Model 2420 uses the SCPI programming language and two remote interface ports (IEEE-488/GPIB and RS-232C).
- Trigger-Link interface to Keithley Series 7000 switching hardware.
- Math expressions — 5 built-in, up to 5 user-defined (bus only).
- Reading and setup storage — Up to 2500 readings and seven setups (five user defaults, factory default, *RST default) can be stored and recalled.
- Closed-cover calibration — The instrument can be calibrated either from the front panel or remote interface.

Warranty information

Warranty information is located at the front of this manual. Should your Model 2420 require warranty service, contact the Keithley representative or authorized repair facility in your area for further information. When returning the instrument for repair, be sure to fill out and include the service form at the back of this manual to provide the repair facility with the necessary information.

Manual addenda

Any improvements or changes concerning the instrument or manual will be explained in an addendum included with the manual. Be sure to note these changes and incorporate them into the manual.

Safety symbols and terms

The following symbols and terms may be found on the instrument or used in this manual.

The symbol on an instrument indicates that the user should refer to the operating instructions located in the manual.

The symbol on the instrument shows that high voltage may be present on the terminal(s). Use standard safety precautions to avoid personal contact with these voltages.

The **WARNING** heading used in this manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading used in this manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

Specifications

Full Model 2420 specifications are included in Appendix A.

Inspection

The Model 2420 was carefully inspected electrically and mechanically before shipment. After unpacking all items from the shipping carton, check for any obvious signs of physical damage that may have occurred during transit. (Note: There may be a protective film over the display lens, which can be removed.) Report any damage to the shipping agent immediately. Save the original packing carton for possible future shipment. The following items are included with every Model 2420 order:

- Model 2420 SourceMeter with line cord.
- Safety test leads (Model 1754).
- Accessories as ordered.
- Certificate of calibration.
- Model 2420 User's Manual (P/N 2420-900-00).
- Model 2420 Service Manual (P/N 2420-902-00).
- Model 2420 Support Software Disk including TestPoint instrument library for GPIB and LabVIEW for Windows driver.

If an additional manual is required, order the appropriate manual package. The manual packages include a manual and any pertinent addenda.

Options and accessories

The following options and accessories are available from Keithley for use with the Model 2420.

General purpose probes

Model 8605 High Performance Modular Test Leads — Consists of two high voltage (1600V) test probes and leads. The test leads are terminated with a banana plug with a retractable sheath on each end.

Model 8606 High Performance Probe Tip Kit — Consists of two spade lugs, two alligator clips, and two spring hook test probes. (The spade lugs and alligator clips are rated at 30V RMS, 42.4V peak; the test probes are rated at 1000V.) These components are for use with high performance test leads terminated with banana plugs, such as the Model 8605.

The following test leads and probes are rated at 30V RMS, 42.4V peak:

Models 5805 and 5805-12 Kelvin Probes — Consists of two spring-loaded Kelvin test probes with banana plug termination. Designed for instruments that measure four-terminal resistance. The Model 5805 is 0.9m long; the Model 5805-12 is 3.6m long.

Model 5806 Kelvin Clip Lead Set — Includes two Kelvin clip test leads (0.9m) with banana plug termination. Designed for instruments that measure four-terminal resistance. A set of eight replacement rubber bands is available (Keithley P/N GA-22).

Model 8604 SMD Probe Set — Consists of two test leads (0.9m), each terminated with a surface mount device "grabber" clip on one end and a banana plug with a retractable sheath on the other end.

Low thermal probes

Model 8610 Low Thermal Shorting Plug — Consists of four banana plugs mounted to a 1-inch square circuit board, interconnected to provide a short circuit among all plugs.

Model 8611 Low Thermal Patch Leads — Consists of two test leads (0.9m), each with a banana plug with a retractable sheath at each end. These leads minimize the thermally-induced offsets that can be created by test leads.

Model 8612 Low Thermal Spade Leads — Consists of two test leads (0.9m), each terminated with a spade lug on one end and a banana plug with a retractable sheath on the other end. These leads minimize the thermally-induced offsets that can be created by test leads.

Cables and adapters

Models 7007-1 and 7007-2 Shielded GPIB Cables — Connect the Model 2420 to the GPIB bus using shielded cables and connectors to reduce electromagnetic interference (EMI). The Model 7007-1 is 1m long; the Model 7007-2 is 2m long.

Models 8501-1 and 8501-2 Trigger Link Cables — Connect the Model 2420 to other instruments with Trigger Link connectors (e.g., Model 7001 Switch System). The Model 8501-1 is 1m long; the Model 8501-2 is 2m long.

Model 8502 Trigger Link Adapter — Lets you connect any of the six Trigger Link lines of the Model 2420 to instruments that use the standard BNC trigger connectors.

Model 8503 DIN to BNC Trigger Cable — Lets you connect Trigger Link lines one (Voltmeter Complete) and two (External Trigger) of the Model 2420 to instruments that use BNC trigger connectors. The Model 8503 is 1m long.

Rack mount kits

Model 4288-1 Single Fixed Rack Mount Kit — Mounts a single Model 2420 in a standard 19-inch rack.

Model 4288-2 Side-by-Side Rack Mount Kit — Mounts two instruments (Models 182, 428, 486, 487, 2000, 2001, 2002, 2010, 2420, 2420, 2420, 6517, 7001) side-by-side in a standard 19-inch rack.

Model 4288-3 Side-by-Side Rack Mount Kit — Mounts a Model 2420 and a Model 199 side-by-side in a standard 19-inch rack.

Model 4288-4 Side-by-Side Rack Mount Kit — Mounts a Model 2420 and a 5.25-inch instrument (Models 195A, 196, 220, 224, 230, 263, 595, 614, 617, 705, 740, 775, etc.) side-by-side in a standard 19-inch rack.

Model 4288-5 Dual Fixed Rack Mounting Kit — Mounts a Model 2420 and another 3½-inch high instrument (Model 182, 428, 486, 487, 2000, 2010, 2400, 2410, 2420 or 7001) side-by-side in a standard 19-inch rack.

Carrying case

Model 1050 Padded Carrying Case — A carrying case for a Model 2420. Includes handles and shoulder strap.

2
Basic Source-Measure Operations

Introduction

This section includes the following information:

- Source-measure concepts
- Front and rear panel familiarization
- Power-up
- Display
- Rules to navigate menus
- Connections
- Basic source-measure procedures
- Basic ohms measurement procedures
- Measure only (V or I)
- Sink operation
- Sweep operation
- Limit testing
- Math (FCTN) operations

WARNING – CAUTION

The SourceMeter uses a heat sink and cooling fan to dissipate heat. The left side of the case is cut out to expose the black, finned heat sink. This heat sink gets hot and could be hot enough to cause burns. Even if the instrument is turned off, you should assume that the heat sink is still hot since it takes considerable time for it to cool off.

WARNING **When handling the SourceMeter, NEVER touch the heat sink located on the left side of the case. This heat sink could be hot enough to cause burns.**

NOTE *See "Cooling fan" for operation details on the 3-speed cooling fan.*

Excessive heat could damage the SourceMeter and at the very least, degrade its performance. The SourceMeter must be operated in an environment where the ambient temperature does not exceed 50°C.

CAUTION **To prevent damaging heat build-up and thus, ensure specified performance, adhere to the following precautions:**

- **Keep the heat sink free of dust, dirt, and contaminates, since its ability to dissipate heat could become impaired.**
- **To keep the bottom cooling vents from becoming blocked, NEVER remove the plastic feet and place the SourceMeter directly on a flat surface. NEVER operate the SourceMeter when it is sitting on a conformable surface (such as a carpet). This also could block the bottom cooling vents.**
- **Do not position any devices adjacent to the SourceMeter that force air (heated or not) into or onto its surfaces or cooling vents. This additional airflow could compromise accuracy performance.**
- **When rack mounting the SourceMeter, make sure there is adequate airflow around the bottom and sides to ensure proper cooling. Adequate airflow enables air temperatures within approximately one inch of the SourceMeter surfaces to remain within specified limits under all operating conditions.**
- **Rack mounting high power dissipation equipment adjacent to the SourceMeter could cause excessive heating to occur. The specified ambient temperatures must be maintained around the surfaces of the SourceMeter to specified accuracies.**
- **A good measure to ensure proper cooling in rack situations with convection cooling only is to place the hottest equipment (i.e., power supply) at the top of the rack. Precision equipment, such as the SourceMeter, should be placed as low as possible in the rack where temperatures are coolest. Adding spacer panels below the SourceMeter will help ensure adequate airflow.**

Source-measure concepts

Operation overview

This operation overview covers the basic source-measure capabilities, explains the Source-Delay-Measure (SDM) cycle, and summarizes the sweep waveforms that can be generated.

Source-measure capabilities

From the front panel, the SourceMeter can be configured to perform the following operations:

- Source Voltage — Display current and/or voltage measurement
- Source Current — Display voltage and/or current measurement
- Measure Resistance — Display voltage or current component of measurement
- Measure Only (V or I) — Display voltage or current measurement

Voltage — The V-Source can output voltage from ±5μV to ±63V and limit current from 10nA to 3.15A. The V-Meter can measure voltage from ±1μV to ±66V. The V-Source and V-Meter each have four ranges; 200mV, 2V, 20V, and 60V.

Current — The I-Source can output current from ±500pA to ±3.15A and limit voltage from 200μV to 63V. The I-Meter can measure current from ±100pA to ±3.3A. The I-Source and I-Meter each have seven ranges; 10μA, 100μA, 1mA, 10mA, 100mA, 1A, and 3A.

Resistance — The SourceMeter can make resistance measurements from <2Ω to >200MΩ. When using the auto ohms measurement method, the following ohms ranges are available: 2Ω, 20Ω, 200Ω, 2kΩ, 20kΩ, 200kΩ, 2MΩ, and 20MΩ. When using the manual ohms measurement method, you cannot select ohms ranges. The ohms reading is the mathematical result of V/I.

Measure only (V or I) — The SourceMeter can be used exclusively as a voltmeter (V-Meter) or an ammeter (I-Meter). When used as a V-Meter only, the I-Source is set to output 0A. When used as an I-meter only, the V-Source is set to output 0V.

Range of operation — The maximum power output of the SourceMeter is 66W. Thus, at maximum source levels, you can output 63V at 1.05A or 21V at 3.15A. The full range of operation is explained in "Overheating protection" and "Operating boundaries".

NOTE ***Output transient recovery*** *— The time required for the V-source to recover to its original value (within 0.1% plus load regulation errors) after a step change in load current is <250μsec. This does not include the response time of autoranging or the second order effects on loads that are not purely resistive.*

Load regulation *— The voltage specification for V-source mode load changes is 0.01% +1mV. This means that on the 200mV range, the load current can be changed from zero to full scale with less than 1.02mV of error. Calculation:*

$$\begin{aligned} error &= (0.01\% \times 0.2V) + 1mV \\ &= 0.02mV + 1mV \\ &= 1.02mV \end{aligned}$$

Assuming a 0 to 1A change in current, the output impedance equates to 1.02mΩ (1.02mV/1A = 1.02mΩ). This level can only be achieved using 4-wire remote sensing.

Compliance limit

When sourcing voltage, you can set the SourceMeter to limit current (from 10nA to 3.15A). Conversely, when sourcing current, you can set the SourceMeter to limit voltage (from 200µV to 63V). The SourceMeter output will not exceed the compliance limit.

NOTE *For the following discussion, "measurement range" refers to the measurement function that is the opposite of the source function. When sourcing voltage, the current measurement range is the point of discussion. Conversely, when sourcing current, the voltage measurement range is the point of discussion.*

There are two types of compliance: "real" and "range." Depending upon which value is lower, the output will clamp at either the displayed compliance setting (real compliance) or at the maximum possible compliance value for the fixed measurement range (range compliance). Range compliance cannot occur if the AUTO measurement range is selected. Thus, to avoid range compliance, use AUTO range.

When in real compliance, the source clamps at the displayed compliance value. For example, if the compliance voltage is set to 1V and the measurement range is 2V, output voltage will clamp at 1V.

When in range compliance, the source output clamps at the maximum possible compliance value for the fixed measurement range (not the compliance value). For example, if compliance is set to 1V and the measurement range is 200mV, output voltage will clamp at 210mV. The maximum compliance values for the measurement ranges are summarized as follows:

Measure range	Maximum compliance value
200mV	210mV
2V	2.1V
20V	21V
60V	63V
10µA	10.5µA
100µA	105µA
1mA	1.05mA
10mA	10.5mA
100mA	105mA
1000mA	1050mA
3A	3.15A

When the SourceMeter goes into real compliance, the "Cmpl" label for the compliance display will flash. When the SourceMeter goes into range compliance, the units label (i.e.,"mA") will instead flash. For the following examples, labels in boldface indicate that they are flashing.

Measurement range:	100mA	
Compliance setting:	**Cmpl:** 075.000 mA	Flashing "Cmpl" indicates that real compliance has occurred. The output is clamped at 75mA.
Measurement range:	10mA	
Compliance setting:	Cmpl: 075.000 **mA**	Flashing "mA" indicates that range compliance has occurred. The output is clamped at 10.5mA.

Determining compliance limit

The relationships to determine which compliance is in effect are summarized as follows:

- Compliance Setting < Measurement Range = Real Compliance
- Measurement Range < Compliance Setting = Range Compliance

You can determine the compliance that is in effect by comparing the displayed compliance setting to the present measurement range. Make sure the correct measurement function is displayed. If sourcing voltage, select the current measurement function. Conversely, if sourcing current, select the voltage measurement function.

If the compliance setting is lower than the maximum compliance value on the present fixed measurement range, then the compliance setting is the compliance limit. If the compliance setting is higher than the measurement range, then the maximum compliance value on that measurement range is the compliance limit.

The following table provides examples for determining the actual compliance limit. For the first three entries in the table, the compliance setting is 50V. On the 60V measurement range, the actual compliance is 50V (compliance setting < measure range = real compliance). On the 20V and 200mV measurement ranges, compliance is 21V and 210mV, respectively (measure range < compliance setting = range compliance). The same rules apply for the next three entries for current compliance.

The last entry shows a compliance setting of 60V with the 60V measurement range selected. The maximum compliance value on the 60V range is 63V. Thus, real compliance is in effect (60V).

Compliance setting		Measurement range		Actual compliance	
Display message	Setting	Display message	Range	Value	Type
Cmpl: 050.000 V	50V	---.---V	60V	50V	Real
Cmpl: 050.000 V	50V	--.----V	20V	21V	Range
Cmpl: 050.000 V	50V	---.---mV	200mV	210mV	Range
Cmpl: 075.000 mA	75mA	---.---mA	100mA	75mA	Real
Cmpl: 075.000 mA	75mA	--.----mA	10mA	10.5mA	Range
Cmpl: 075.000 mA	75mA	-.-----mA	1mA	1.05mA	Range
Cmpl: 060.000 V	60V	---.---V	60V	60V	Real

Over the bus, use the appropriate SCPI commands to determine the measurement range and the compliance setting. Once those parameters are known, you can compare them as previously explained to determine the compliance that is in effect.

When sourcing current, use the following commands to acquire the measurement range and the compliance setting:

VOLTage:RANGe?	Query voltage measurement range.
VOLTage:PROTection?	Query voltage compliance limit.

When sourcing voltage, use the following commands to acquire the measurement range and the compliance setting:

CURRent:RANGe?	Query current measurement range.
CURRent:PROTection?	Query current compliance limit.

Source-delay-measure cycle

In addition to static source and/or measure operation, SourceMeter operation can consist of a series of source-delay-measure (SDM) cycles (see Figure 2-1). During each SDM cycle, the following occurs:

1. Set the source output level.
2. Wait for the delay.
3. Make the measurement.

When the source is turned on (triggered), an approximate 100µsec trigger latency occurs before the programmed source level is output.

As long as the source output stays on, trigger latency will not be included in subsequent SDM cycles. Trigger latency only occurs when the output makes the transition from off to on.

The delay phase of the SDM cycle is used to allow the source to settle before the measurement is performed. The delay period depends on how the source delay is configured. The source delay can be manually set from 000.0000 seconds to 9999.998 seconds. If using auto delay, the delay depends on which source range is presently selected. When on the 3A I-Source range, enabling auto delay sets the delay to 2msec. When on any other source range (V or I), enabling auto delay sets the delay to 1msec. See "Source configuration" in Section 3 for details on setting the source delay.

The manually set delay (up to 9999.998 sec) is available to compensate for longer settling required by external circuitry. The more capacitance seen at the output, the more settling time required for the source. The actual delay period needed can be calculated or determined by trial and error. For purely resistive loads and at higher current levels, the programmable delay can be set to 0msec.

The measure time depends on the selected measurement speed. For example, if speed is set at 0.01 PLC (power line cycles), the measure time would be 167µsec for 60Hz operation (0.01/60).

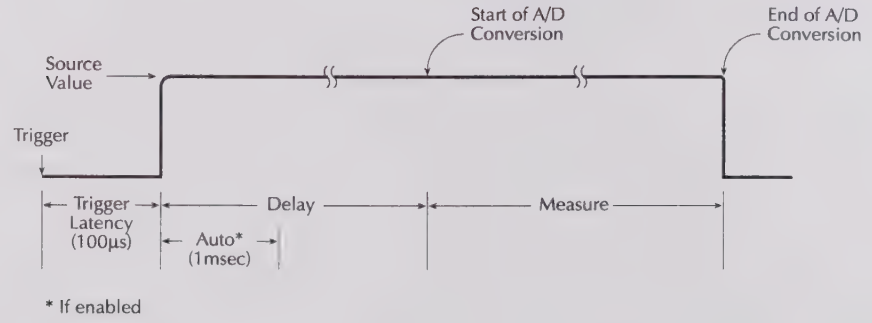
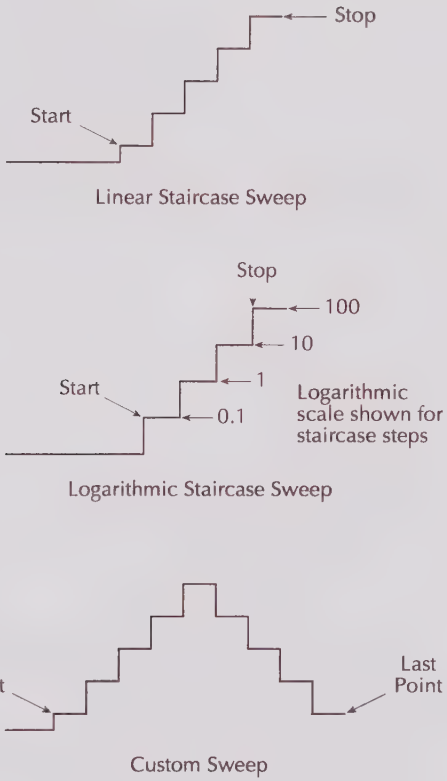


Figure 2-1
Source-delay-measure (SDM) cycle

Figure 2-2
Three basic sweep waveform types



Sweep waveforms

There are four basic sweep types to select from: Linear Staircase, Logarithmic Staircase, Custom, and Source Memory. Three of the sweeps are shown in Figure 2-2. The linear staircase sweep goes from the start level to the stop level in equal linear steps. The logarithmic staircase sweep is similar except that it is done on a log scale with a specified number of steps per decade. The custom sweep lets you construct your own sweep by specifying the number of measure points and the source level at each point. For a source memory sweep, up to 100 setup configurations can be saved in memory. When the sweep is performed, the setup at each memory point is recalled.

An SDM cycle is performed on each step (or point) of the sweep. Thus, one measurement will be performed at each step (level). The time spent at each step (level) depends on how the SDM cycle is configured (i.e., source delay, measure speed) and the trigger delay (if used).

Typical applications for staircase sweeps include: I-V curves for 2- and 3- terminal semiconductor devices, characterization of leakage vs. voltage, and semiconductor breakdown. Pulse sweeps are used in applications where thermal response is measured or where sustained power

levels can damage the external device under test. Source memory sweeps are used in applications where multiple source-measure functions and/or math expressions are required.

The custom sweep can be used to configure a pulse sweep with a 50% duty cycle. For example, a 1V pulse sweep can be configured by programming the odd numbered points for 1V and the even numbered points for 0V. When the sweep is run, the output will alternate between 1V and 0V.

After a sweep is run, the data is stored in the sweep buffer. This data can be accessed from the front panel or sent to a computer (remote operation) for evaluation (i.e., plotting). Statistical information on readings stored in the buffer are also available from the front panel.

Overheating protection

Cooling fan — A cooling fan is used to help keep the Model 2420 from overheating. Proper ventilation is required for this fan to be effective. See the WARNING - CAUTION located at the beginning of Section 2 for details on maintaining proper ventilation. See "Cooling fan" for operation details on the 3-speed cooling fan.

Over-temperature shutdown — The SourceMeter has an over-temperature protection circuit that will turn the output off in the event that the SourceMeter overheats. If the output trips due to overheating, a message indicating this condition will be displayed. You will not be able to turn the output back on until the SourceMeter cools down.

Overheating prevention power equations

Assuming the cooling fan is working and proper ventilation is maintained, the SourceMeter will not overheat (and subsequently turn off the output) when the SourceMeter is operating as a source (not sink) and the ambient temperature is ≤30°C.

Above 30°C, for both source and sink operation, the SourceMeter will not overheat if the high power ranges are not used. The high power ranges are 20V, 3A and 60V, 1A.

NOTE *See "Operating boundaries" for details on source and sink operation.*

For all other operating conditions, you can use the following equations to determine if the SourceMeter will overheat.

There are two equations for each of the high power voltage ranges (20V and 60V). Both of the equations for the selected voltage range must be true to ensure that the SourceMeter will not overheat. The result of the first equation must be ≤ 100, and the result of the second equation must be ≤ 85.

For the power equations:

Iout = SourceMeter measured current* (in amps)
Vout = SourceMeter measured voltage* (in volts)
DC = Duty cycle** (0 to 1) (i.e., 50% = 0.5)
Tamb = Ambient temperature (0° to 50°C)

* For sink operation, Iout or Vout (but not both) must be a negative number. The exception is |Iout|, which is a magnitude (absolute value).

** If a duty cycle of less than 1 is required for the equations to be true, then the maximum output on-time must be less than 10 seconds.

20V range power equations

$$\{[(33 \times |Iout|) - (Vout \times Iout)] \times DC \times 0.7\} + Tamb \leq 100$$

and

$$\{[30 + (|Iout| \times 40 \times DC)] \times 0.35\} + Tamb \leq 85$$

60V range power equations

$$\{[(76 \times |Iout|) - (Vout \times Iout)] \times DC \times 0.7\} + Tamb \leq 100$$

and

$$\{[30 + (|Iout| \times 120 \times DC)] \times 0.35\} + Tamb \leq 85$$

Operating boundaries

Source or sink

Depending on how it is programmed and what is connected to the output (load or source), the SourceMeter can operate in any of the four quadrants. The four quadrants of operation are shown in Figure 2-3. When operating in the first (I) or third (III) quadrant, the SourceMeter is operating as a source (V and I have the same polarity). As a source, the SourceMeter is delivering power to a load.

When operating in the second (II) or fourth (IV) quadrant, the SourceMeter is operating as a sink (V and I have opposite polarity). As a sink, it is dissipating power rather than sourcing it. An external source or an energy storage device, such as a capacitor or battery, can force operation in the sink region. See "Sink operation" for more information.

The general operating boundaries for the SourceMeter are shown in Figure 2-3. In this drawing the 3A, 20V and 1A, 60V magnitudes are nominal values. The actual maximum output magnitudes of the SourceMeter are 3.15A, 21V and 1.05A, 63V. These operating boundaries are valid only if the SourceMeter is being operated in an environment where the ambient temperature is 30°C or less.

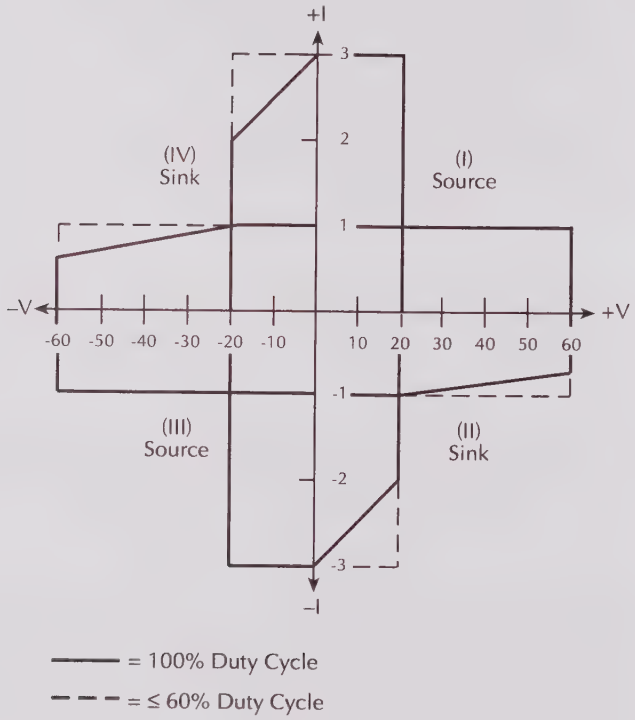
NOTE *Above 30°C, high power operation could overheat the SourceMeter, causing the output to turn off. See "Overheating protection" and "Overheating prevention power equations" for details.*

The heavy solid lines show the limits for continuous output operation. Note that in quadrants II and IV (sink operation), the limits are derated as follows:

3A range — limits linearly derated from:	-3A, 0V to -2A, 20V 3A, 0V to 2A, -20V
1A range — limits linearly derated from:	-1A, 20V to -0.7A, 60V 1A, -20V to 0.7A, -60V

If the output duty cycle is decreased to 60% or less, sink operation limits are restored to normal as shown by the dotted lines in Figure 2-3.

Figure 2-3
Operating boundaries



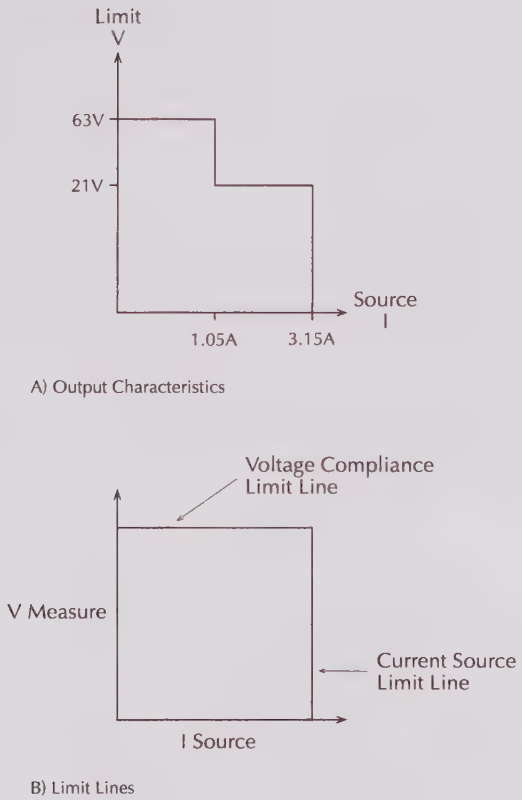
I-Source operating boundaries

Figure 2-4 shows the operating boundaries for the I-Source. Only the first quadrant of operation is covered. Operation in quadrant III is similar.

Figure 2-4A shows the output characteristics for the I-Source. As shown, the SourceMeter can output up to 1.05A at 63V, or 3.15A at 21V. Maximum power at these levels is 66.15W. Note that when sourcing more than 1.05A, voltage is limited to 21V.

Figure 2-4B shows the limit lines for the I-Source. The current source limit line represents the maximum source value possible for the presently selected current source range. For example, if on the 100mA current source range, the current source limit line is at 105mA. The voltage compliance limit line represents the actual compliance that is in effect. Remember that compliance can be real or range (see "Compliance limit"). These limit lines are boundaries that represent the operating limits of the SourceMeter for this quadrant of operation. The operating point1 can be anywhere inside (or on) these limit lines. The limit line boundaries for the other quadrants are similar.

Figure 2-4
I-Source boundaries



Where within the boundaries the SourceMeter operates depends on the load (DUT) that is connected to its output. Figure 2-5 shows operation examples for resistive loads that are 100Ω and 400Ω respectively. For these examples, the SourceMeter is programmed to source 100mA and limit 20V.

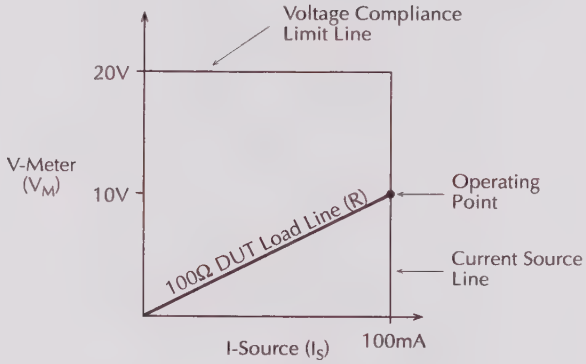
In Figure 2-5A, the SourceMeter is sourcing 100mA to the 100Ω load and subsequently measures 10V. As shown, the load line for 100Ω intersects the 100mA current source line at 10V.

Figure 2-5B shows what happens if the resistance of the load is increased to 400Ω. The DUT load line for 400Ω intersects the voltage compliance limit line placing the SourceMeter in compliance. In compliance, the SourceMeter will not be able to source its programmed current (100mA). For the 400Ω DUT, the SourceMeter will only output 50mA (at the 20V limit).

Notice that as resistance increases, the slope of the DUT load line increases. As resistance approaches infinity (open output), the SourceMeter will source virtually 0mA at 20V. Conversely, as resistance decreases, the slope of the DUT load line decreases. At zero resistance (shorted output), the SourceMeter will source 100mA at virtually 0V.

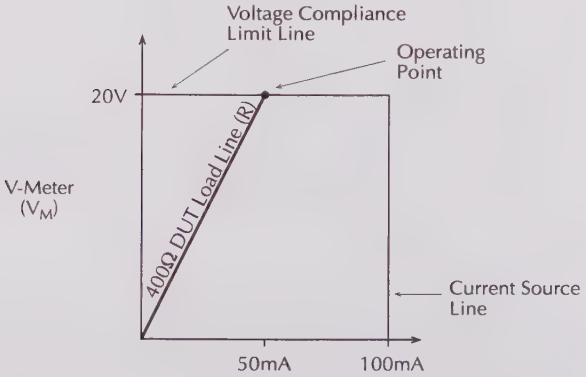
Regardless of the load, voltage will never exceed the programmed compliance of 20V.

Figure 2-5
I-source operating examples



$V_M = I_S \cdot R$
$= (100mA)\ (100\Omega)$
$= 10V$

A) Normal I-source operation



$I_S = V_M / R$
$= 20V / 400\Omega$
$= 50mA$

B) I-source in compliance

V-Source operating boundaries

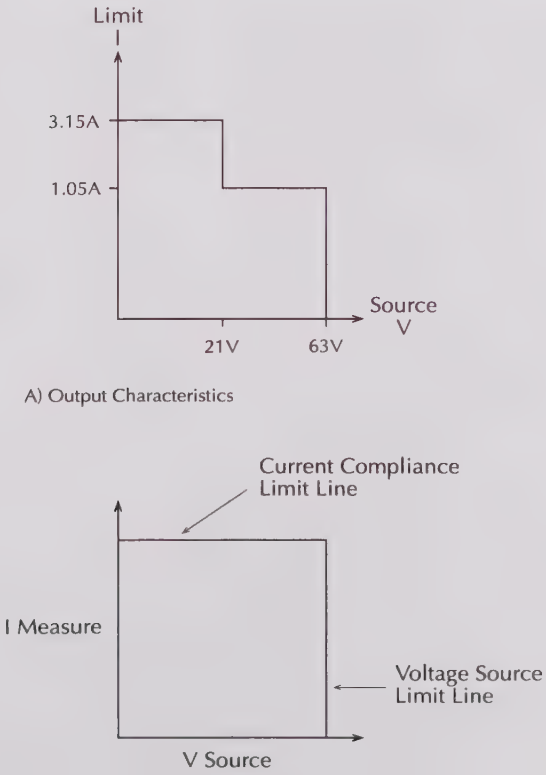
Figure 2-6 shows the operating boundaries for the V-Source. Only the first quadrant of operation is covered. Operation in quadrant III is similar.

Figure 2-6A shows the output characteristics for the V-Source. As shown, the SourceMeter can output up to 21V at 3.15A , or 63V at 1.05A. Maximum power at these levels is 66.15W. Note that when sourcing more than 21V, current is limited to 1.05A.

Figure 2-6B shows the limit lines for the V-Source . The voltage source limit line represents the maximum source value possible for the presently selected voltage source range. For example, if on the 20V source range, the voltage source limit line is at 21V. The current compliance limit line represents the actual compliance in effect. Remember that compliance can be real or range (see "Compliance limit"). These limit lines are boundaries that represent the operating limits of the SourceMeter for this quadrant of operation. The operating point can be anywhere inside (or on) these limit lines. The limit line boundaries for the other quadrants are similar.

Where within the boundaries the SourceMeter operates depends on the load (DUT) that is connected to the output. Figure 2-7 shows operation examples for resistive loads that are 10kΩ and 4kΩ, respectively. For these examples, the SourceMeter is programmed to source 50V and limit 10mA.

Figure 2-6
V-source boundaries



In Figure 2-7A, the SourceMeter is sourcing 50V to the 10kΩ load and subsequently measures 5mA. As shown, the load line for 10kΩ intersects the 50V voltage source line at 5mA.

Figure 2-7B shows what happens if the resistance of the load is decreased to 4kΩ. The DUT load line for 4kΩ intersects the current compliance limit line placing the SourceMeter in compliance. In compliance, the SourceMeter will not be able to source its programmed voltage (50V). For the 4kΩ DUT, the SourceMeter will only output 40V (at the 10mA limit).

Notice that as resistance decreases, the slope of the DUT load line increases. As resistance approaches infinity (open output), the SourceMeter will source virtually 50V at 0mA. Conversely, as resistance increases, the slope of the DUT load line decreases. At zero resistance (shorted output), the SourceMeter will source virtually 0V at 10mA.

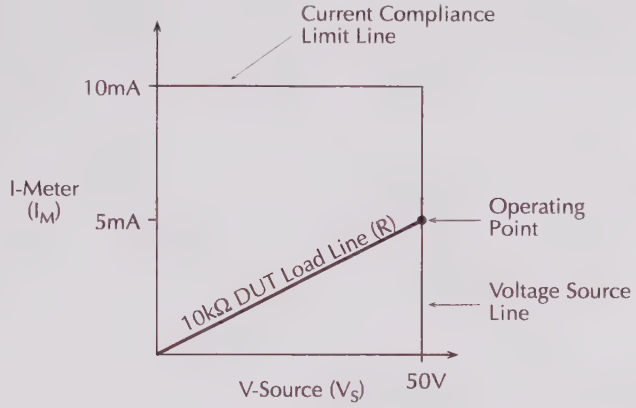
Regardless of the load, current will never exceed the programmed compliance of 10mA.

Source I measure I and source V measure V

The SourceMeter has the ability to measure the function that it is sourcing. When sourcing a voltage, you can measure voltage. Conversely, if you are sourcing current, you can measure the output current. For these measure source operations, the measure range is the same as the source range.

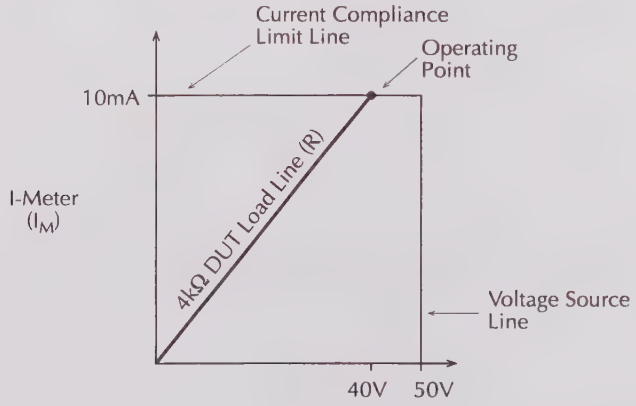
This feature is valuable when operating with the source in compliance. When in compliance, the programmed source value is not reached. Thus, measuring the source allows you to measure the actual output voltage. With the use of the TOGGLE key, you can display the measurement of any two of the three functions (volts, amps, and ohms) concurrently. For remote operation, you can measure all three functions concurrently (see Sections 4 and 5).

Figure 2-7
V-source operating examples



$I_M = V_S / R$
$= 50V/10k\Omega$
$= 5mA$

A) Normal V-source operation



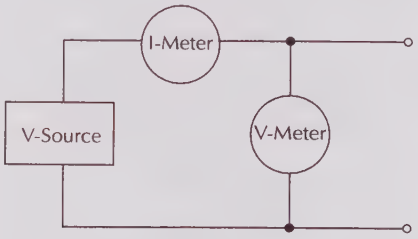
$V_S = I_M \cdot R$
$= (10mA)\ (4k\Omega)$
$= 40V$

B) V-Source in compliance

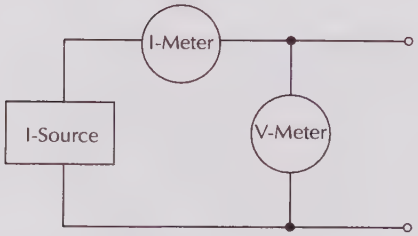
Basic circuit configurations

The fundamental source-measure configurations for the SourceMeter are shown in Figure 2-8. When sourcing voltage, you can measure current or voltage (configuration A). When sourcing current, you can measure voltage or current (configuration B).

Figure 2-8
Fundamental source-measure configuration



A. Source V



B. Source I

These simple configuration models are expanded to include the driven guard and sense circuits and are shown in Figures 2-9 and 2-10. See "Guard" for more information.

Source I

When configured to source current (I-Source) as shown in Figure 2-9, the SourceMeter functions as a high-impedance current source with voltage limit capability and can measure current (I-Meter) or voltage (V-Meter).

For voltage measurements, the sense selection (2-wire local or 4-wire remote) determines where the measurement is made. In local sense, voltage is measured at the Input/Output terminals of the SourceMeter.

In 4-wire remote sense, voltage can be measured directly at the DUT using the Sense terminals. This eliminates any voltage drops that may be in the test leads or connections between the SourceMeter and the DUT.

NOTE *The current source does not require or use the sense leads to enhance current source accuracy.*

With 4-wire remote sensing selected, the sense leads must be connected or incorrect operation will result. Over-voltage protection (OVP) can be used if the potential for sense lead disconnection exists (see "Source configuration; protection" in Section 3).

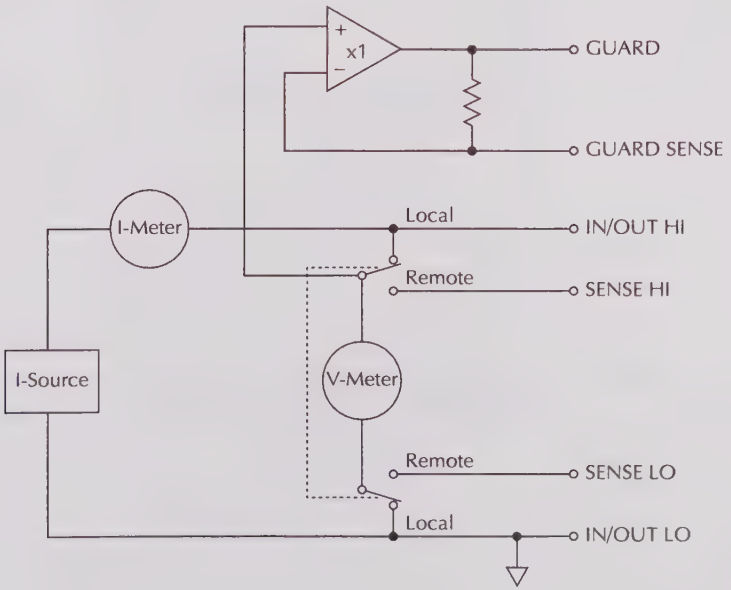


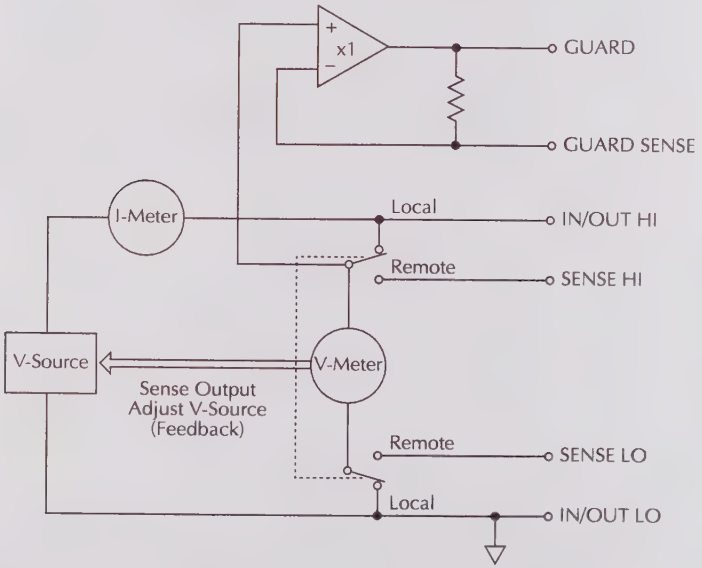
Figure 2-9
Source I

Source V

When configured to source voltage (V-Source) as shown in Figure 2-10, the SourceMeter functions as a low-impedance voltage source with current limit capability and can measure current (I-Meter) or voltage (V-Meter).

Sense circuitry is used to continuously monitor the output voltage and make adjustments to the V-Source as needed. The V-Meter senses the voltage at the Input/Output terminals (2-wire local sense) or at the DUT (4-wire remote sense using the sense terminals) and compares it to the programmed voltage level. If the sensed level and the programmed value are not the same, the V-Source is adjusted accordingly. Remote sense eliminates the effect of voltage drops in the test leads ensuring that the exact programmed voltage appears at the DUT.

Figure 2-10
Source V



NOTE *The voltage error feedback to the V-Source is an analog function. The source error amplifier is used to compensate for IR drop in the test leads.*

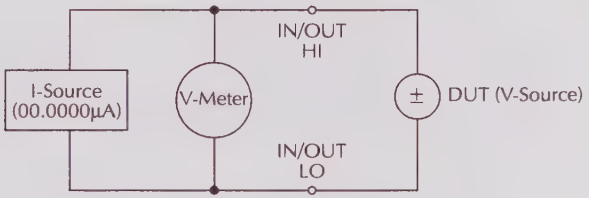
Measure only (V or I)

Figure 2-11 shows the configurations for using the SourceMeter exclusively as a voltmeter or ammeter. As shown in Figure 2-11A, the SourceMeter is configured to measure voltage only by setting it to source 0A and measure voltage.

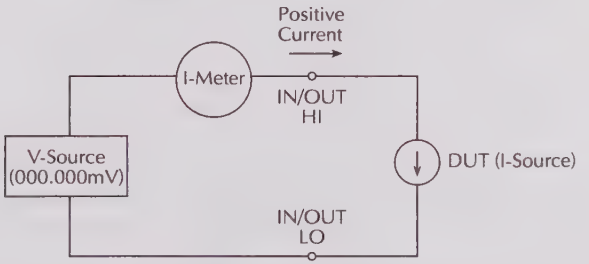
CAUTION **V-Compliance must be set to a level that is higher than the measured voltage. Otherwise, excessive current will flow into the SourceMeter. This current could damage the SourceMeter. Also, when connecting an external voltage to the I-Source, set the output off state to the high-impedance mode (see "Configure operate" in Section 3).**

In Figure 2-11B, the SourceMeter is configured to measure current-only by setting it to source 0V and measure current. Note that in order to obtain positive (+) readings, conventional current must flow from IN/OUT HI to LO.

Figure 2-11
Measure only (V or I)



A. Measure voltage only



NOTE: Positive current flowing out of IN/OUT HI results in positive (+) measurements.

B. Measure current only

NOTE: Use 2-wire local sensing.

Guard

WARNING **GUARD is at the same potential as output HI. Thus, if hazardous voltages are present at output HI, they are also present at the GUARD terminal.**

The driven guard (available at the rear panel GUARD terminal) is always enabled and provides a buffered voltage that is at the same level as the Input/Output HI (or Sense HI for remote sense) voltage. The purpose of guarding is to eliminate the effects of leakage current (and capacitance) that can exist between input/output high and low. In the absence of a driven guard, leakage in the external test circuit could be high enough to adversely affect the performance of the SourceMeter.

Leakage current can occur through parasitic or non-parasitic leakage paths. An example of parasitic resistance is the leakage path across the insulator in a coax or triax cable. An example of non-parasitic resistance is the leakage path through a resistor that is connected in parallel to the DUT.

There are two programmable output impedance levels for the guard output. The high-impedance (~10kΩ) CABLE guard is used to reduce the effects of capacitance and leakage current paths in the test circuit. The low-impedance (<1Ω) OHMS guard is used to cancel the effects of parallel resistances when measuring a resistor element of a resistor network.

Cable guard

The CABLE guard selection provides a high-impedance (~10kΩ) driven guard to prevent positive feedback, which could cause oscillations when using shielded cables. Cable guard is used to drive the shields of cables and test fixtures. Guard is extended to a test fixture using a safety banana plug (such as the Model 8008-BAN). Inside the test fixture, the guard can be connected to a guard plate or shield that surrounds the DUT.

WARNING **To prevent injury or death, a safety shield must be used to prevent physical contact with a guard plate or guard shield that is at a hazardous potential (>30Vrms or 42.4V peak). This safety shield must completely enclose the guard plate or shield and must be connected to safety earth ground. Figure 2-12B shows the metal case of a test fixture being used as a safety shield.**

Inside the test fixture, a triaxial cable can be used to extend guard to the DUT. The center conductor of the cable is used for In/Out HI, the inner shield is used for guard, and the outer shield is used for In/Out LO and is connected to the safety shield (which is connected to safety earth ground).

A coaxial cable can be used if the guard potential does not exceed 30Vrms (42.4V peak). The center conductor is used for In/Out HI, and the outer shield is used for guard. For higher guard potentials, use a triaxial cable as previously explained.

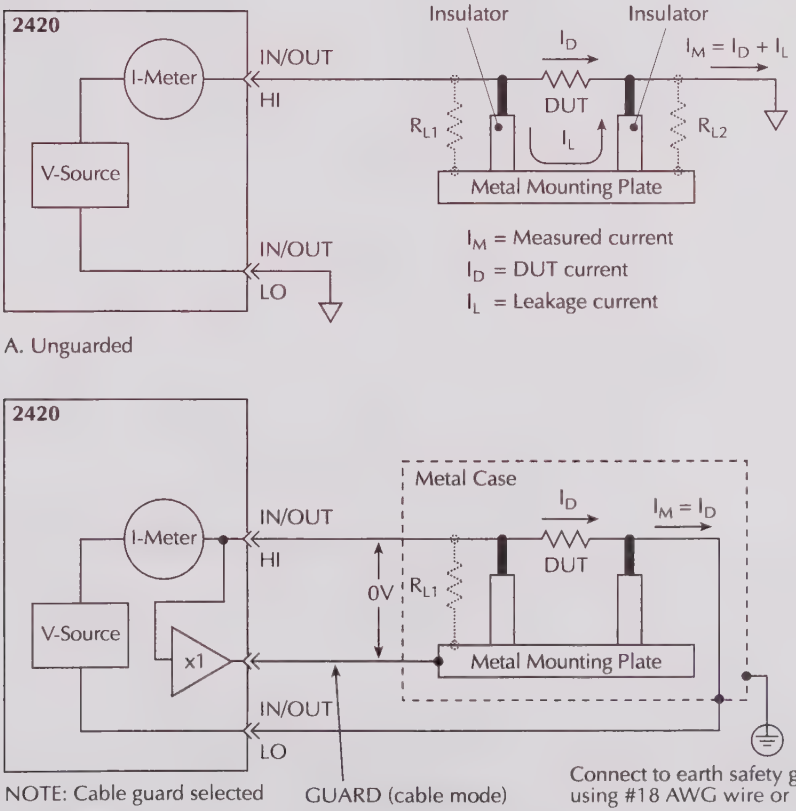
Figure 2-12 shows how cable guard can eliminate leakage current through the insulators in a test fixture. In Figure 2-12A, leakage current (I_L) flows through the insulators (R_{L1} and R_{L2}) to In/Out LO, adversely affecting the low-current (or high-resistance) measurement of the DUT.

In Figure 2-12B, the driven guard is connected to the metal guard plate for the insulators. Since the voltage on either end of R_{L1} is the same (0V drop), no current can flow through the leakage resistance path. Thus, the SourceMeter only measures the current through the DUT.

Cable guard should be used when sourcing or measuring low current (<1μA).

NOTE *When using shielded, triaxial, or coaxial cabling with guard, the CABLE guard setting must be used to prevent oscillations. CABLE guard is the factory default setting.*

Figure 2-12
High-impedance measurements



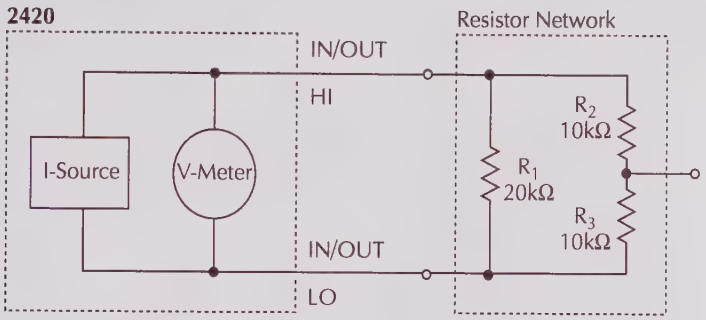
Ohms guard

The OHMS guard selection provides a low-impedance (<1Ω), high current (up to 50mA) driven guard. This allows you to perform in-circuit ohms measurements of the DUT where other parallel resistive paths are present. These measurements are typically performed in Delta or Wye configurations.

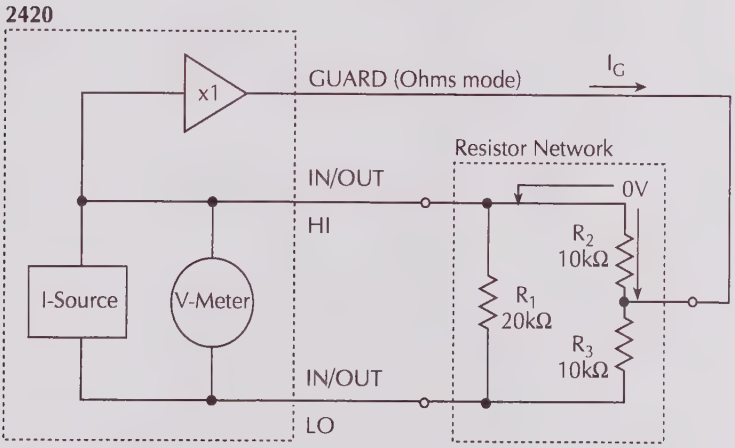
NOTE *Ohms guard is not available for the 1A and 3A ranges (source and measure). Ohms guard cannot be selected if already on one of these ranges. Conversely, if ohms guard is already selected, the 1A and 3A ranges cannot be selected.*

If you want to measure the resistance of a single resistor in the network, you must use the ohms guard configuration. Figure 2-13B shows how to measure the resistance of R1. Since the voltage on either side of R2 is the same, no current can flow through it. Thus, all the programmed current (I_M) from the SourceMeter will flow through R1. The voltage across R1 is then measured, and an accurate resistance measurement is calculated, in this case 20kΩ.

NOTE *Guard current (I_G) must not exceed 50mA. If it does, the guard voltage drops lower than the output voltage allowing leakage current. Thus, the guarded ohms measurement becomes corrupted.*



A. Unguarded



NOTE: Ohms guard selected

$$I_G = \frac{V_M}{R_3}$$

B. Guarded

Figure 2-13
In-circuit ohms measurements

Guard Sense — When the GUARD-to-LO resistance path is less than 1kΩ, remote guard sensing should be used to compensate for IR drop in the GUARD test lead and/or switch contacts on a switching card.

In Figure 2-14A, Figure 2-13 was modified by changing the value of R3 to 100Ω and showing the 1Ω resistance (R_{TL}) of the GUARD test lead. Since the resistance path from GUARD-to-LO is less than 1kΩ, the IR drop in the guard test lead (R_{TL}) becomes significant. The guard voltage applied to the bottom of R2 is now significantly lower than the In/Out HI voltage of the SourceMeter. As a result, leakage current (I_L) flows through R2 adversely affecting the resistance measurement of R1.

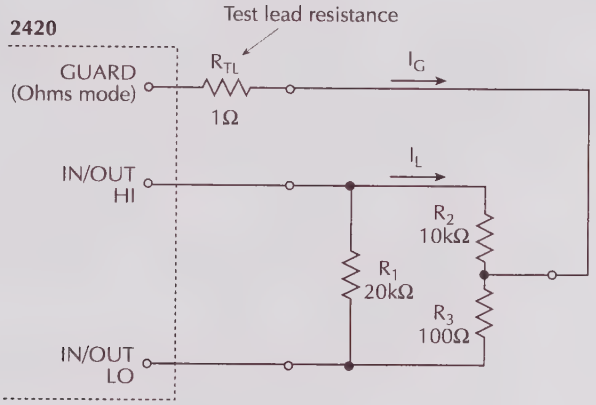
The guard test lead IR drop is compensated for by connecting GUARD SENSE as shown in Figure 2-14B. Sensing allows the guard voltage to be sensed (measured) at the resistor network for better guard voltage regulation. If the remotely sensed guard voltage is less than the output voltage of the SourceMeter, the guard voltage will be increased until the sensed guard voltage equals the output HI voltage.

Note that in order to ensure that guard current (I_G) in Figure 2-14 does not exceed 50mA, output voltage from the SourceMeter must not exceed 5V (50mA × 100Ω = 5V).

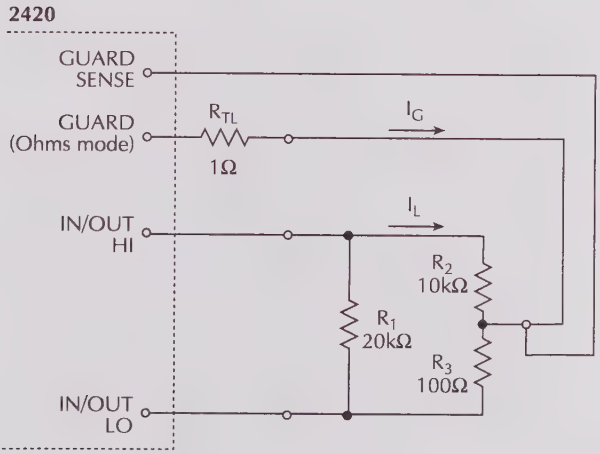
NOTES *Guard sense operation is automatic. There is no menu selection to enable or disable guard sense.*

For 6-wire ohms guard measurements, use the GUARD output-off state. For details on the GUARD output-off state, see "Configure output."

Figure 2-14
In-circuit ohms measurements using guard sense



A. Local guard sense



B. Remote guard sense

Data flow

Data flow for front panel operation is summarized by the block diagrams provided in Figure 2-15. Note that if REL is enabled, the result of the rel operation is sent to the other blocks.

With Math (FCTN) and Limit Tests (LIMITS) disabled (see Figure 2-15A), the SourceMeter displays the measurement readings. If the data store is used, these readings are also stored in the buffer for later recall. Statistical data for these readings is also available upon recall.

Figure 2-15B shows data flow when Math or Limit Tests is enabled. If Math is enabled, the result of the math operation is displayed. If Limit Tests is enabled, the raw reading along with the results of the tests (pass or fail) is displayed. As in the previous case, these readings can also be stored in the data store.

Figure 2-15C shows data flow when both Math and Limit Tests are enabled. The Math operation is performed first, and then limit tests are performed on that math result. The result of the math operation and the result of the limit tests (pass or fail) are displayed. As shown, these readings can also be stored in the data store.

Buffer considerations

When the SourceMeter is in the process of storing readings, configuration changes affect what gets stored in the buffer. These storage considerations and restrictions are summarized in the following table.

Configuration at start of the storage process	What happens if the basic measurement function (V, I, or Ω) is changed	What happens if the MATH function is changed	What happens if REL or LIMITS is changed
Measure V, I, or Ω	Buffer tracks	V, I, or Ω stored- MATH not stored	V, I, or Ω stored- REL or Limits not stored
MATH (FCTN) enabled	Buffer pauses	OK	MATH stored- REL or Limits not stored
REL/LIMITS enabled	Buffer pauses	Buffer pauses	OK

The first column of the table shows the SourceMeter configuration when the storage process is started. The next three columns show what happens when configuration changes are made while the SourceMeter is storing readings.

Changing V, I, or Ω measurement function

If you started with only a basic measurement function selected, the buffer will track a basic measurement function change. For example, if you started in volts and changed to current, the buffer will store the current readings.

If you started with MATH, REL, and/or LIMITS enabled, the buffer will stop storing readings if you change the basic measurement function. Storage will continue if you return to the original configuration.

Changing MATH function

If you started with only a basic measurement function selected, you can enable a MATH function, but only the voltage, current, or resistance component of the calculation will be stored in the buffer. The results of the MATH function will not be stored.

If you started with a MATH function enabled, you can select a different MATH function. The results of the new MATH function are stored in the buffer.

If you started with REL and/or LIMITS enabled, the buffer will stop storing readings if you select a MATH function. Storage will continue if you return to the original configuration.

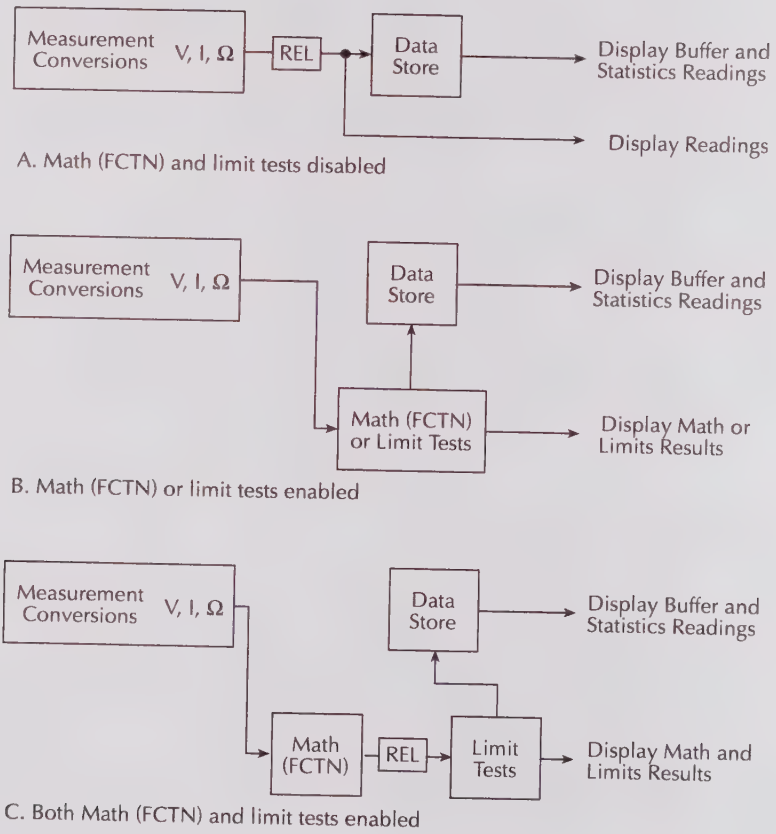
Changing REL or LIMITS

If you started with only a basic measurement function selected, you can enable REL and/or LIMITS, but only the voltage, current, or resistance component of the operation will be stored in the buffer. The results of REL and/or LIMITS are not stored.

If you started with a MATH function enabled, only the result of the MATH calculation will be stored in the buffer if REL and/or LIMITS is enabled.

If you started with REL and/or LIMITS enabled, you can change REL and or LIMITS. The results of the new REL and/or LIMITS are stored in the buffer.

Figure 2-15
Data flow – front panel



Front and rear panel familiarization

Front panel summary

The front panel of the Model 2420 SourceMeter is shown in Figure 2-16. The following abbreviated information should be reviewed before operating the instrument.

Figure 2-16
Model 2420 front panel

Measurement (MEAS) function keys:

V	Measure volts.
I	Measure amps.
Ω	Measure ohms.
FCTN	Perform math functions.

SOURCE function keys:

V	Source voltage (V-Source).
I	Source current (I-Source).
▲	Increase source or compliance value.
▼	Decrease source or compliance value.

Operation keys:

EDIT	Select source or compliance reading for editing.
TOGGLE	Toggle display positions of source and measure readings, or display V and I measurements.
LOCAL	Cancel remote operation.
REL	Enable/disable relative reading on present function.
FILTER	Display digital filter status for present function and toggle filter on/off.
LIMIT	Perform configured limit tests.
TRIG	Trigger a measurement from the front panel.
SWEEP	Start configured sweep.
◀ and ▶	Move through parameter values or selections within functions and operations.
DIGITS	Change number of digits of display resolution.
SPEED	Change measurement speed by selecting accuracy or specifying NPLC.
STORE	Set buffer size and enable reading storage.
RECALL	Display stored readings and timestamp.
CONFIG	Press CONFIG and then appropriate key to configure function or operation.
MENU	Access and configure Main Menu selections.
EXIT	Cancels selection. Use to back out of menu structures.
ENTER	Accepts selection.

RANGE keys:

▲	Moves to next higher range, increments digit, moves to next selection.
▼	Moves to next lower range, decrements digit, moves to previous selection.
AUTO	Enables or disables measurement auto range.

Annunciators:

EDIT	Instrument in edit mode.
ERR	Questionable reading, invalid cal step.
REM	Instrument in GPIB remote mode.
TALK	Instrument addressed to talk over GPIB.
LSTN	Instrument addressed to listen over GPIB.
SRQ	Service request over GPIB.
REAR	Rear input/output connectors selected.
REL	Relative measure reading displayed.
FILT	Digital filter enabled.
MATH	Math function enabled.
4W	Remote sensing enabled.
AUTO	Autoranging enabled.
ARM	Source-measure operations being performed.
TRIG	External trigger source selected.
*	Reading being stored.

Input/output connectors:

INPUT/OUTPUT HI and LO Use to source-measure volts, amps, and ohms.
4-WIRE SENSE HI and LO Use for 4-wire remote sensing.

Input/output controls:

ON/OFF	Turns the source on or off.
FRONT/REAR	Selects front or rear panel input connections.

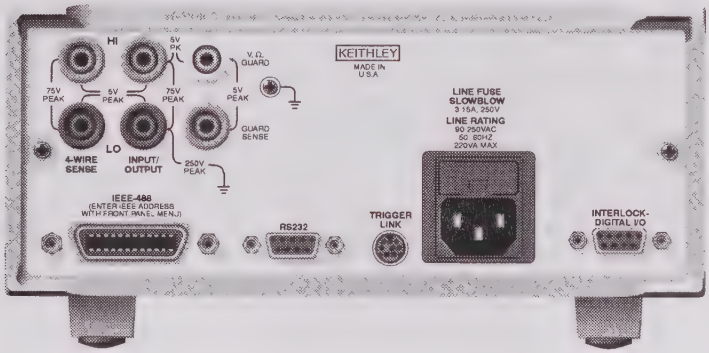
Handle:

Pull out and rotate to desired position.

Rear panel summary

The rear panel of the Model 2420 SourceMeter is shown in Figure 2-17. The following abbreviated information should be reviewed before operating the instrument.

Figure 2-17
Model 2420 rear panel



Input/output connectors:

INPUT/OUTPUT HI and LO	Use to source-measure volts, amps and ohms.
4-WIRE SENSE HI and LO	Use for 4-wire remote sensing.
V, Ω GUARD	Driven guard for guarded measurements.
GUARD SENSE	Use to correct for IR drops in Guard Output lead.

Pem nut with screw Earth (chassis) ground.

WARNING **INPUT/OUTPUT LO is not internally connected to the chassis and can float up to 250V peak above chassis ground.**

Interlock and digital input/output port:

INTERLOCK – DIGITAL I/O Connector for digital output lines, interlock, and component handler signals.

Power module:

Contains the AC line receptacle and the power line fuse.

Trigger link connector:

TRIGGER LINK 8-pin micro-DIN connector for sending and receiving trigger pulses. Use a trigger link cable or adapter, such as Models 8501-1, 8501-2, 8502, 8504.

RS-232 connector:

RS-232 Connector for RS-232 remote operation. Use a straight through (not null modem) DB-9 cable.

GPIB connector:

IEEE-488 INTERFACE Connector for GPIB remote operation. Use a shielded cable (Model 7007-1 or 7007-2).

Power-up

Line power connection

The Model 2420 operates from a line voltage in the range of 90 to 250V at a frequency of 50 or 60Hz. The SourceMeter will also operate at 400Hz; accuracy specifications are not guaranteed however. Line voltage is automatically sensed, thus there are no switches to set. Check to see that the operating voltage in your area is compatible.

At the factory, the SourceMeter is configured to sense the power line frequency and automatically select the frequency setting. If, however, the line frequency is noisy, the SourceMeter may select the wrong setting on power-up. If this occurs, noisy measurement readings will result, and accuracy performance may be affected. During the power-on sequence, the selected line frequency setting is displayed.

The line frequency can be manually set (50Hz or 60Hz) from the A/D CONTROLS option of the GENERAL MENU (see "Main menu" in Section 3). For 400Hz operation, use the 50Hz setting.

CAUTION **Operating the instrument on an incorrect line voltage may cause damage to it, possibly voiding the warranty.**

Perform the following steps to connect the SourceMeter to line power and turn it on:

1. Before plugging in the power cord, make sure the front panel power switch is in the off (0) position.
2. Connect the female end of the supplied power cord to the AC receptacle on the rear panel.

WARNING **The power cord supplied with the Model 2420 contains a separate ground for use with grounded outlets. When proper connections are made, instrument chassis is connected to power line ground through the ground wire in the power cord. Failure to use a grounded outlet may result in personal injury or death due to electric shock.**

3. Turn on the instrument by pressing the front panel power switch to the on (1) position.

Fuse replacement

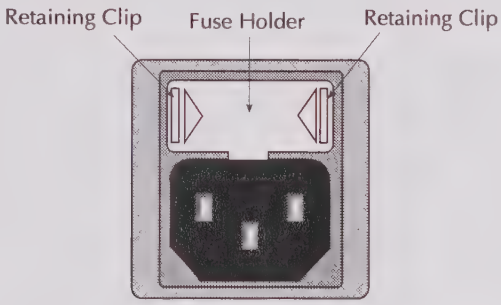
A rear panel fuse protects the power line input of the SourceMeter. If the line fuse needs to be replaced, perform the following steps:

1. The fuse holder is located above the AC receptacle (see Figure 2-18) and is held into the power module by two retaining clips. To remove the fuse holder, simultaneously push the two retaining clips towards each other and pull the fuse holder out of the power module.
2. Remove the fuse and replace it with the same type (250V, 3.15A, 5 × 20mm). The Keithley part number is FU-106-3.15.

CAUTION **For continued protection against fire or instrument damage, only replace the fuse with the type and rating listed. If the instrument repeatedly blows fuses, locate and correct the cause of the problem before replacing the fuse.**

3. Install the fuse holder into the power module by pushing it in until it locks in place.

Figure 2-18
Power module



Power-up sequence

On power-up, the Model 2420 performs self-tests on its EPROM and RAM and momentarily lights all segments and annunciators. If a failure is detected, the instrument momentarily displays an error message, and the ERR annunciator turns on (error messages are listed in Appendix B).

NOTE *If a problem develops while the instrument is under warranty, return it to Keithley Instruments, Inc., for repair.*

If the instrument passes the self-tests, the firmware revision levels are displayed. For example:

REV A01 A02

where: A01 is the main board ROM revision.
A02 is the display board ROM revision.

Also displayed is the line frequency (50, 60, or 400Hz). If the wrong line frequency is displayed, use the MENU→GENERAL→A/D CNTRL→LINE FREQUENCY selection to change it.

The communication interface status is briefly displayed. If the IEEE-488 bus is the presently selected interface, the identification message will include the primary address. For example, if the primary address is 24 (factory default), the "IEEE Addr=24" message is displayed. If the RS-232 interface is selected, the "RS-232" message is displayed.

After the power-up sequence, the instrument goes to its normal display state with the output off (red OUTPUT indicator light off). With the output off, the "OFF" message is displayed, and dashes replace the reading.

Cooling fan

A 3-speed cooling fan is used to help keep the Model 2420 from overheating. Proper ventilation must be maintained in order for the fan to be effective. Refer to the "WARNING - CAUTION" located at the beginning of Section 2 for details on maintaining proper ventilation.

With the OUTPUT ON, the fan speed setting is determined by the present current range (source or measure):

Range	Fan speed
10µA, 100µA, 1mA	Low (50%)
10mA, 100mA	Medium (75%)
1A, 3A	High (100%)

When the OUTPUT is turned OFF, the fan will either run at the low speed or stay at the speed it was at when the output was on (current range dependent). This speed option is set from the FAN selection of the GENERAL MENU (see "Main menu" in Section 3).

Note that you will be able to hear changes in fan speed.

Display

The display of the Model 2420 is used primarily to program source and compliance values and display measured readings. Annunciators are located along the top of the reading/message display. The annunciators indicate various states of operation (see "Front panel summary").

On power-up, the top (primary) display is used for measurements when the output is on (with the output off, "OFF" is displayed). The bottom-left display is used for the programmed source value (Vsrc or Isrc), and the bottom-right display is used for the programmed compliance (Cmpl) limit.

Edit key

The SourceMeter must be in the edit mode to set source and compliance values. The edit mode is selected by pressing the EDIT key (EDIT annunciator on). The editing cursor (flashing digit) appears for the source or compliance reading. If a value is not edited within six seconds, the edit mode is canceled. While in the edit mode, the EDIT key toggles between the source value and compliance value. See "Basic source-measure procedure" for details on setting source and compliance values.

Toggle key

The TOGGLE key manipulates readings on the top display and on the bottom-left display. It has no effect on the compliance reading (Cmpl), which is located on the bottom right. Each press of the TOGGLE key sequences through the display options.

With the voltage (V) or current (I) measurement function selected, the TOGGLE key lets you display both the current and voltage measurements at the same time. It also lets you toggle display positions of the source and measure readings.

With the ohms (Ω) measurement function selected, the ohms measurement is always displayed on the top display. The TOGGLE key allows you to display either the programmed source value, the current measurement, or the voltage measurement on the bottom-left display.

The TOGGLE key is also used to display statistical data on readings stored in the data store. This is performed from the data store RECALL mode.

NOTE *If FCTN, REL, or Limits is enabled, the TOGGLE key is disabled.*

Status and error messages

Status and error messages are displayed momentarily. During SourceMeter operation and programming, you will encounter a number of front panel messages. Typical messages are either status or error in nature and are listed in Appendix B.

Rules to navigate menus

Many source-measure functions and operations are configured from front panel menus. Use the following rules to navigate through these configuration menus:

NOTE *Rules to edit source and compliance values are found in the "Basic source-measure procedure."*

- A menu item is selected by placing the cursor on it and pressing ENTER. Cursor position is denoted by the blinking menu item or option. The cursor keys (◄ and ►) control cursor position.
- A displayed arrow (◄ and ►) on the bottom line indicates that there are one or more additional items (or messages) to select from. Use the appropriate cursor key to display them.
- A source or parameter value range is changed by placing the cursor on the range designator (i.e., k, M, G, etc.) and using the SOURCE or RANGE ▲ and ▼ keys. Note that when the next higher or lower source range is selected, the reading increases or decreases by a decade.
- A parameter value is keyed in by placing the cursor on the digit to be changed and using one of the following methods:
  - Use the SOURCE or RANGE ▲ and ▼ keys to increment or decrement the selected digit.
  - Use the number keys (0 through 9) to key in the value at the selected digit. Note that the ± key can be used to change the polarity of a source value regardless of where the cursor is positioned.
- Boolean selections (such as ON/OFF and HIGH/LOW) are toggled by placing the cursor on the selection and pressing a SOURCE ▲ or ▼ key or a RANGE ▲ or ▼ key.
- A change is only executed when ENTER is pressed. Entering an invalid parameter generates an error, and the entry is ignored. However, entering an out-of-range value (too small or too large) selects the lower or upper limit respectively.
- The EXIT key is used to back out of the menu structure. Any change that is not entered is cancelled when EXIT is pressed.

Connections

WARNING **To prevent electrical shock that could cause injury or death, NEVER make or break connections to the SourceMeter while the output is on (red OUTPUT indicator light on). If on, press the ON/OFF key to turn the output off ("OFF" message displayed).**

Front/rear terminals selection

The OUTPUT (HI and LO) and SENSE (HI and LO) terminals are accessible from both the front and rear panels. The GUARD, GUARD SENSE, and EARTH (chassis ground) terminals are only accessible from the rear panel. The FRONT/REAR TERMINALS key is used control which set of terminals is connected to the SourceMeter. Pressing this key toggles the SourceMeter connections between the front and rear terminals. When the "REAR" annunciator is on, the rear terminals are connected to the SourceMeter. When "REAR" is off, the front terminals are selected.

NOTE *When the FRONT/REAR TERMINALS key is pressed, the OUTPUT will turn OFF.*

Test fixture interlock

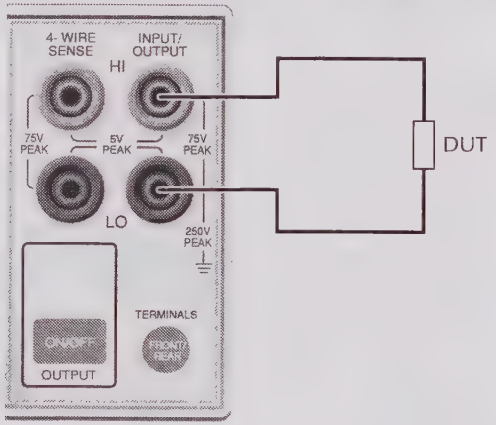
A test fixture interlock switch can be used with the SourceMeter to help protect the DUT. The SourceMeter output will turn off when the lid of the test fixture is opened. However, the user must ALWAYS assume that power is present until it is verified that the SourceMeter output is off.

WARNING **To prevent electric shock, test connections must be configured such that the user cannot come in contact with conductors or any DUT that is in contact with the conductors. Safe installation requires proper shields, barriers, and grounding to prevent contact with conductors. Operator protection and safety are the responsibility of the person installing the product.**

Connections to DUT

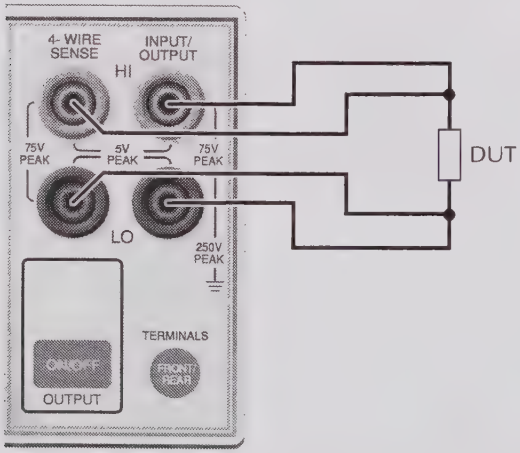
Basic source-measure operations are performed using either 2-wire local sense connections (see Figure 2-19) or 4-wire remote sense connections (see Figure 2-20). The factory default sense selection is local. See "Sense selection" to check and/or change the sense selection.

Figure 2-19
Two-wire connections (local sense)



2420 Front Panel Sense Selection: 2-wire

Figure 2-20
Four-wire connections (remote sense)



2420 Front Panel Sense Selection: 4-wire

NOTE *Connections alone do not determine sense mode. For local sensing (Figure 2-19), 2-wire sensing must be selected from the SENSE MODE option of the CONFIGURE V-SOURCE menu. For remote sensing (Figure 2-20), 4-wire sensing must be selected. See "Source configuration" in Section 3 for details on sense mode selection. The 2-wire sense mode is the BENCH and GPIB default.*

4-wire remote sensing

When sourcing and/or measuring voltage, there can be errors associated with IR drops in the test leads. Voltage source and measure accuracy are optimized by using 4-wire remote sense connections. When sourcing voltage, 4-wire remote sensing ensures that the programmed voltage is delivered to the DUT. When measuring voltage, only the voltage drop across the DUT is measured. Use 4-wire remote sensing for the following source-measure conditions:

- Test circuit impedance is <1kΩ.
- Optimum Ohms, V-Source, and/or V-Measure accuracy are required.

NOTE *Specified accuracies for both source and measure are only achieved by using 4-wire remote sensing.*

WARNING **When sourcing voltage in remote sense, make sure the sense leads are connected to the DUT. If a sense lead becomes disconnected, 0V will be sensed, and the SourceMeter will increase the output voltage (to possibly hazardous levels) to compensate. For increased safety, you can limit the voltage the SourceMeter can output. See "Configure V-source; protection" in Section 3 to limit the output voltage level.**

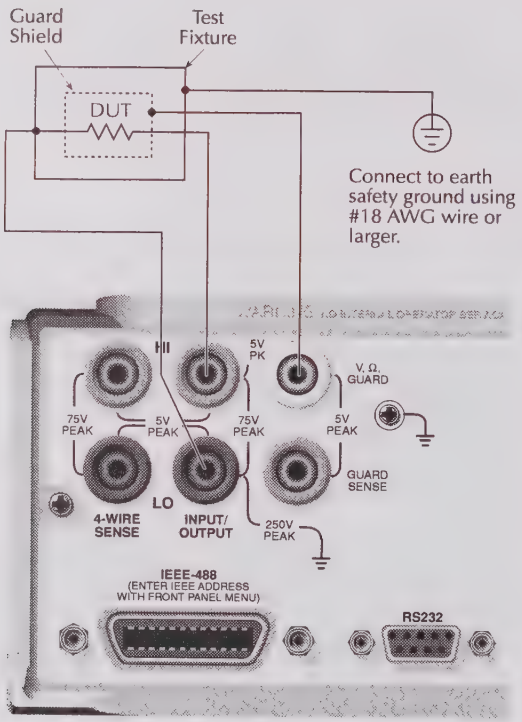
2-wire local sensing

2-wire local sense connections can only be used if the error contributed by test lead IR drop is acceptable to the user. At current levels below 100mA, the errors are usually not significant (assuming test lead resistance is not greater than 1Ω).

Since current in a series circuit is the same at all points in the loop, remote sensing does not improve I-Source or I-Measure accuracy. Thus, if sourcing current and measuring current, you can use local sensing. Other conditions that allow the use of 2-wire local sensing include:

- Test circuit impedance is ≥1kΩ. Above 1GΩ, guarding should also be used (see "Cable guard").
- Measure Only (V or I) operation.

Figure 2-21
High-impedance guarding



Cable guard

Use the high-impedance (cable) guard connection scheme shown in Figure 2-21 for the following source-measure condition:

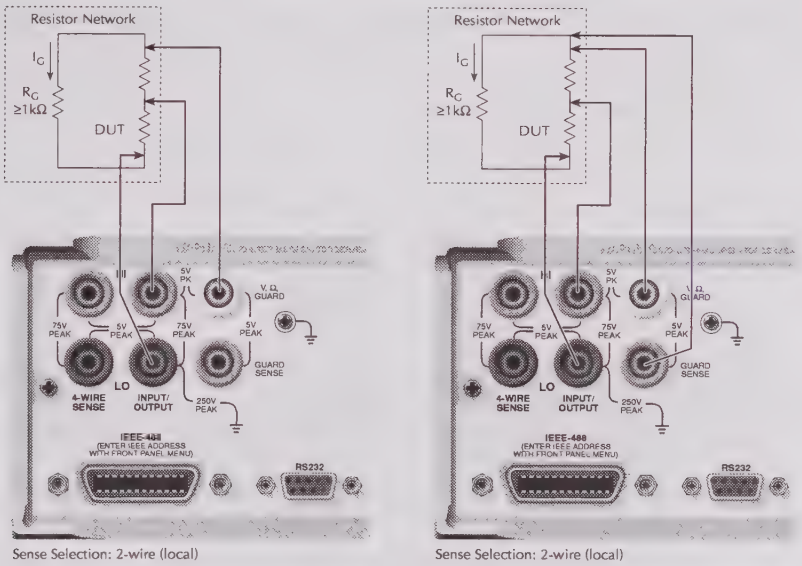
- Test circuit impedance is >1GΩ.

Note that CABLE guard must be selected for this connection scheme. See "Guard selection" to select cable guard.

A test fixture is typically used when testing high-impedance devices. The test fixture reduces noise and protects the user from a potentially hazardous voltage on the guard shield (or plate). See "Basic circuit configurations; guard" for details on using guard.

Note that the test fixture chassis is connected to In/Out LO to reduce noise.

Figure 2-22
Guarded ohms measurements



Ohms guard

Use the guarded ohms connection schemes shown in Figure 2-22 for the following source-measure operation:

- In-circuit resistance measurements on DUT where other parasitic leakage devices are present.

Note that OHMS guard must be selected for this connection scheme. Ohms guard is not available for the 1A or 3A ranges (source or measure). See "Guard selection" to select ohms guard.

Figure 2-22 shows how to make connections to measure the resistance of a single resistor (DUT) in a resistor network. See "Basic circuit configurations; guard" for more information on guarded ohms measurements.

The basic connection scheme for guarded ohms measurements is shown in Figure 2-22A. If the guard resistance path (R_G) is <1kΩ, IR drop in the GUARD test lead could be high enough that the guard voltage at the resistor network is significantly less than the output voltage at the DUT. This results in leakage current and will corrupt the measurement. To cancel the effect of IR drop in the GUARD test lead, connect GUARD SENSE to the resistor network as shown in Figure 2-22B. Guard sense ensures that the guard voltage at the resistor network is the same as the output voltage at the DUT.

Note that if the DUT is <1kΩ, you should use the 4-wire measurement method (remote sensing) by connecting SENSE HI and LO to the DUT and enabling remote sense.

NOTE *Guard current (I_G) must never exceed 50mA. If it does, guard voltage will become less than the output voltage and corrupt the measurement.*

Sense and guard selections

NOTE When sense or guard settings are changed, the OUTPUT will turn OFF.

Sense selection

When using the SENSE HI and LO terminals of the SourceMeter, 4-wire remote sensing must be selected. When not using these terminals, local sensing must be selected. Sense selection is explained as follows. See "Basic source-measure configurations" for details on sense.

NOTE The SourceMeter defaults to the 2-wire (local) sense mode when the output is off, regardless of the sense setting. When the output is turned on, the present sense setting will be in effect.

On power-up, the instrument is automatically set for 2-wire local sense. Perform the following steps to check and/or change the sense selection:

1. Press CONFIG and then the SOURCE V, MEAS V, or Ω key. Changing sense in one configuration menu changes it in all of the others.
2. For SOURCE V and Ω, use the ◄ and ► keys to place the cursor (flashing menu item) on SENSE MODE and press ENTER.

NOTE Cursor position indicates the present sense selection. Two-wire indicates that local sense is selected, and 4-wire indicates that remote sense is selected. To retain the present selection, use the EXIT key to back out of the menu structure and skip the next two steps.

3. To change the sense selection, place the cursor on 4-wire to select remote sense or on 2-wire to select local sense, and press ENTER.
4. Use the EXIT key to back out of the menu structure.

Guard selection

Cable guard is used for high-impedance guarding for cables (i.e., coax and triax) and test fixtures. Ohms guard provides a high-current guard output, which allows in-circuit guarded ohms measurements. On power-up, cable guard is selected. Perform the following steps to check or change the guard selection:

1. Press CONFIG and then the SOURCE V, SOURCE I, or Ω. Changing guard in one configuration menu changes it in all of the others.
2. Using the ◄ and ► keys, place the cursor (flashing menu item) on GUARD and press ENTER.

NOTE Cursor position indicates the present guard selection (OHMS or CABLE). To retain the present selection, use the EXIT key to back out of the menu structure and skip the next two steps.

3. To change the guard selection, place the cursor on the alternate selection and press ENTER.
4. Use the EXIT key to back out of the menu structure.

NOTES 1) Do not use Ohms guard with coaxial cabling, or oscillations may occur.
2) Ohms guard cannot be selected in on the 1A or 3A range (source or measure).

Basic source-measure procedure

Use the following procedure to perform the basic source-measure operations of the SourceMeter. See "Basic ohms measurement procedures" to measure ohms.

NOTE *The following procedure assumes that the SourceMeter is already connected to the DUT as explained in "Connections".*

WARNING **To prevent electric shock, do not make or break connections to the SourceMeter with the output on. If on, press the ON/OFF OUTPUT key to turn the output off.**

1. Select source.

   Press SOURCE V to select the V-Source or press SOURCE I to select the I-Source. The presently programmed source value (Vsrc or Isrc) and compliance level (Cmpl) are displayed. Note that the "OFF" message is displayed to indicate that the source is off (red ON/OFF indicator off).

2. Set source level and compliance limit.

   The source level is the voltage or current setting of the selected source (V-Source or I-Source). A compliance limit is set to protect the DUT from damaging currents or voltages. When using the V-Source, a current compliance is set. When using the I-Source, a voltage compliance is set. Compliance defines the maximum absolute value the SourceMeter can output.

   Note that compliance could instead be determined by the measurement range. Depending on which value is lower, compliance occurs at the programmed value (real compliance) or at the maximum compliance value for the present fixed measurement range (range compliance). For example, with compliance set to 2V and the 200mV measurement range selected, compliance will occur at 210mV. On the 60V meaurement range compliance will occur at 2V. See "Compliance limit" in "Source-measure concepts" for details on real and range compliance.

NOTES *The SourceMeter must be in the edit mode (EDIT annunciator ON) to set source and compliance values. The edit mode is selected by pressing the EDIT key. The flashing digit for the source or compliance reading indicates that the SourceMeter is in the edit mode. If no editing operation is performed within six seconds, the edit mode times out and is canceled. To return to the edit mode, press EDIT again. While in the edit mode, the EDIT key toggles between the source value and the compliance value.*

The SOURCE ▲, SOURCE ▼, ◀ and ▶ keys also enable the edit mode. They select the last selected field.

When editing the source value, the source is updated immediately. This allows you to "tweak" the source value while the output is on.

The source value cannot be changed while the SourceMeter is performing a sweep. This occurs with Output ON and either the SWEEP key is pressed, Offset Compensation is enabled under Ohms, or OFF-COMP-OHMS, VOLT-COEFF, or VAR-ALPHA functions are enabled.

When editing the compliance value, compliance is not updated until ENTER is pressed or the edit mode is allowed to time out.

EDIT always goes to the source field first.

Source and compliance values cannot be edited in AUTO OHMS mode.

Perform the following steps to edit the source and compliance values:

A. Press EDIT to enter the edit mode. The flashing digit indicates which reading (source or compliance) is presently selected for editing. If you wish to edit the other field, press EDIT again.

B. Use the RANGE ▲ and ▼ keys to select a range that will accommodate the value you want to set. For best accuracy, use the lowest possible source range.

C. Enter the desired source or compliance value. There are two methods to edit the value: value adjust and numeric entry.

- **Value adjust** — To adjust the value, use the ◄ and ► keys to place the cursor at the appropriate position, and use the SOURCE ▲ and ▼ keys to increment or decrement the value.
- **Numeric entry** — When the edit mode is entered, the cursor is located on the most significant digit of the value. From this position, you can key in the value using the number keys (0 through 9). After each number is keyed in, the cursor moves one position to the right. If desired, you can use the ◄ and ► keys to place the cursor on a digit to be changed, and press the appropriate number key. The ± key toggles the polarity of the source value. Note that the cursor does not have to be on the polarity sign of the value to change polarity. The MENU key resets the source value to zero (0V or 0A).

D. To edit the other field, press EDIT to select it and repeat steps B and C.

E. When finished editing the source and compliance values, press ENTER or wait six seconds to exit from the edit mode.

NOTE *When a compliance limit value is entered, the SourceMeter will automatically go to the lowest (most sensitive) compliance range that will accommodate that value.*

The lowest compliance levels that can be set are 00.0100μA (10nA) and 000.200mV (200μV).

3. Select measurement function and range.

   Select the desired measurement function by pressing MEAS V (voltage) or MEAS I (current).

   When measuring the source (i.e., Source V Measure V), you cannot select the range using the measurement RANGE keys. The selected source range determines the measurement range.

   When not measuring the source (i.e., Source V Measure I), measurement range selection can be done manually or automatically. When using manual ranging, use the lowest possible range for best accuracy. In autorange, the SourceMeter automatically goes to the most sensitive range to make the measurement.

   Measuring voltage — When sourcing current, you can use the RANGE ▲ and ▼ keys to manually select the voltage measurement range. You can also press AUTO to select autoranging. When sourcing voltage, the RANGE keys are inoperative.

   Measuring current — When sourcing voltage, you can use the RANGE ▲ and ▼ keys to manually select the current measurement range. You can also press AUTO to select autoranging. When sourcing current, the RANGE keys are inoperative.

NOTE *With the 60V V-Source range selected, the highest current measurement range is 1A. With the 3A I-Source range selected, the highest voltage measurement range is 20V.*

Measurement range is also limited by the compliance setting. For example, if voltage compliance is 1V (2V compliance range), the highest voltage measurement range that can be selected is 2V.

4. Turn output on.

   Turn the output on by pressing the ON/OFF OUTPUT key. The red OUTPUT indicator will turn on to indicate that the output is on.

5. Observe readings on display.

   The SourceMeter is in compliance if the "Cmpl" label or the units label (i.e. "mA") for the displayed compliance setting is flashing. If the "Cmpl" label is flashing, real compliance has occurred. The output is clamped at the displayed compliance value. If the units label is flashing, range compliance has occurred. The output is clamped at the maximum compliance value for the present fixed measurement range. For example, if presently on the 2V measurement range, a flashing units label for the voltage compliance reading indicates that the output is clamped at 2.1V.

The SourceMeter can be taken out of compliance (real or range) by going into the edit mode and decreasing the source value or increasing the compliance value. Note that increasing the compliance limit may compromise protection for the DUT. If in range compliance, selecting a higher measurement range may take the SourceMeter out of compliance.

NOTE *See "Compliance limit" in "Source-measure concepts" for details on real and range compliance.*

6. Turn output off.

   When finished, turn the output off by pressing the ON/OFF OUTPUT key. The red OUTPUT indicator light will turn off.

Basic ohms measurement procedures

There are two methods to measure ohms. When using auto ohms, the SourceMeter operates as a conventional "constant current source" ohmmeter. Select an ohms measurement range (or use autorange) and take the reading from the display.

For manual ohms, the SourceMeter uses the V/I measurement method. After configuring the desired source and selecting a voltage or current measurement range, select the Ω measurement function to display the calculated V/I ohms reading. For manual ohms, use either the I-Source or the V-Source.

NOTE *To achieve optimum accuracy for front panel operation, the SourceMeter measures both V and I and uses these values in the ohms calculation. The measured source value is more accurate than the programmed source value. For remote operation, the user specifies the functions to measure.*

Selecting ohms measurement method

On power-up, auto ohms is the default method for the ohms function. Perform the following steps to check and/or change the ohms measurement method:

1. Press CONFIG and then Ω to display the ohms configuration menu.
2. Using the ◄ and ► keys, place the cursor (flashing menu item) on SOURCE and press ENTER.

NOTE *Cursor position indicates the presently selected ohms measurement method. To retain this selection, use the EXIT key to back out of the menu structure and skip the next two steps.*

3. To change the measurement method, place the cursor on the alternate selection (AUTO or MANUAL) and press ENTER.
4. Press EXIT to exit from the menu structure.

Auto ohms measurements

Perform the following steps to perform auto ohms measurements:

NOTE *The following procedure assumes that the SourceMeter is already connected to the DUT as explained in "Connections."*

WARNING **To prevent electric shock, do not make or break connections to the SourceMeter with the output on. If on, press the ON/OFF OUTPUT key to turn the output off.**

1. Select ohms measurement function.

   Press MEAS Ω to select the ohms measurement function.

2. Select auto ohms measurement method.

   Select the auto ohms measurement method as previously explained (see "Selecting ohms measurement method"). Notice that the SourceMeter will be configured to Source I Measure V. Note that the I-Source level and V-compliance limit are based on the measurement range and cannot be edited.

3. Select measurement range.

   Use the RANGE ▲ and ▼ keys to select a range appropriate for the expected ohms reading, or use autorange by pressing AUTO. When using manual ranging, selecting the most sensitive (lowest) range provides the best accuracy. Autorange automatically goes to the most sensitive range.

4. Turn output on.

   Turn the output on by pressing the ON/OFF OUTPUT key. The red OUTPUT indicator will turn on to indicate that the output is on.

5. Observe reading on display.

   The SourceMeter will go into compliance if you exceed the maximum ohms measurement range (>22MΩ).

6. Turn output off.

   When finished, turn the output off by pressing the ON/OFF OUTPUT key. The red OUTPUT indicator light will turn off.

Manual ohms measurements

Perform the following steps to perform manual ohms measurements.

NOTE *The following procedure assumes that the SourceMeter is already connected to the DUT as explained in "Connections".*

WARNING **To prevent electric shock, do not make or break connections to the SourceMeter with the output on. If on, press the ON/OFF OUTPUT key to turn the output off.**

1. Select ohms measurement function.

   Press MEAS Ω to select the ohms measurement function.

2. Select manual ohms measurement method.

   Select the manual ohms measurement method as previously explained (see "Selecting ohms measurement method").

3. Configure source.

   For manual ohms, you can Source I or Source V at the user-programmed output level. The lowest allowable compliance limit is based on the load and the source value. For example, if sourcing 1V to a 1kΩ resistor, the lowest allowable current compliance is 1mA (1V/1kΩ = 1mA). Setting a limit lower than 1mA will place the source in compliance. Refer to steps 1 and 2 of the "Basic source-measure procedure" to configure the source.

NOTE *Use the V-Source for manual ohms measurements when high-speed settling is required (i.e., production testing).*

4. Select measurement range.

   Using the RANGE keys, select the lowest possible fixed range or use AUTO range. Note that if sourcing current, you will be setting the voltage measurement range. Conversely, if sourcing voltage, you will be setting the current measurement range. The most sensitive measurement range provides the best accuracy.

   For range restrictions, refer to the NOTE in step 3 of the "Basic source-measure procedure."

5. Turn output on.

   Turn the output on by pressing the ON/OFF OUTPUT key. The red OUTPUT indicator will turn on to indicate the output is on.

6. Observe reading on display.

   The SourceMeter is in compliance if the "Cmpl" label or the units label (i.e. "mA") for the displayed compliance setting is flashing. If the "Cmpl" label is flashing, real compliance has occurred. The output is clamped at the displayed compliance value. If the units label is flashing, range compliance has occurred. The output is clamped at the maximum compliance value for the present fixed measurement range. For example, if presently on the 2V measurement range, a flashing units label for the voltage compliance reading indicates that the output is clamped at 2.1V.

The SourceMeter can be taken out of compliance (real or range) by going into the edit mode and decreasing the source value or increasing the compliance value. Note that increasing the compliance limit may compromise protection for the DUT. If in range compliance, selecting a higher measurement range may take the SourceMeter out of compliance.

NOTE *See "Compliance limit" in "Source-measure concepts" for details on real and range compliance.*

7. Turn output off.

   When finished, turn the output off by pressing the ON/OFF OUTPUT key. The red OUTPUT indicator light will turn off.

Offset-compensated Ω

The presence of thermal EMFs (V_{EMF}) can adversely affect low-resistance measurement accuracy. To overcome these unwanted offset voltages use the offset-compensated ohms measurement method.

In general, this method measures resistance (V/I) at a specific source level and then subtracts a resistance measurement made with the source set to zero. With the source set to zero, the source level is V_{EMF}. Thus, the resistance contributed by the presence of V_{EMF} is eliminated.

This two-point measurement method is mathematically expressed as:

Offset Compensated $\Omega = \Delta V / \Delta I$ where $\Delta V = V2 - V1$ and $\Delta I = I2 - I1$.

V1 is the voltage measurement with the source set to a specific level. V2 is the voltage measurement with the source set to zero. I1 is the current measurement with the source set to a specific level. I2 is the current measurement with the source set to zero.

For auto ohms, the SourceMeter will select the appropriate current source level and voltage measurement range. For manual ohms, first select the appropriate source (V or I) value while the output is off. When the source is turned on, the output will cycle between the programmed value and zero (0A or 0V) to derive the offset-compensated ohms measurement.

NOTE *Manual offset-compensated ohms is also available as a math (FCTN) operation. This math function allows you to specify both source values.*

Enabling/disabling offset-compensated ohms

Offset-compensated ohms is enabled or disabled from the OFFSET COMPENSATION option of the CONFIG OHMS menu as follows:

1. Press CONFIG and then Ω to display the ohms configuration menu.
2. Place the cursor on OFFSET COMPENSATION and press ENTER.
3. Place the cursor over ON (to enable compensation) or OFF (to disable compensation), and press ENTER.
4. Use the EXIT key to exit the menu structure.

Offset-compensated ohms procedure

NOTE *The following procedure assumes that the desired ohms measurement method (auto or manual) is already selected and the SourceMeter is connected to the DUT as explained in "Connections." Refer to "Selecting ohms measurement method" to check or change the measurement method.*

1. Turn the output off.
2. Select Ω measurement function.
3. Enable offset compensation as previously explained (see "Enabling/disabling offset-compensated ohms").

NOTE *If using the auto ohms measurement method, go to step 5.*

4. For manual ohms measurements, configure the desired source (V or I) to output the appropriate source level. Set compliance and select a measurement range (or use AUTO range). See steps 1, 2, and 3 of the "Basic source-measure procedure" for details.
5. Turn the output on and observe the offset-compensated ohms reading on the display. Note that the source alternates between the programmed output value and zero.

NOTE *When the output is turned off, the displayed source value may be zero (0V or 0A) (usually it will be the previously programmed value in Manual Ohms mode). However, the programmed source value is remembered and will be used when the output is turned back on. If a new source value is programmed, the SourceMeter will use the new source value when the output is turned back on. The source value cannot be changed while the output is on. If a global setup or source memory location is saved, the previously programmed source value will always be stored.*

6. When finished, turn the output off and disable offset-compensated ohms.

Measure only (V or I)

Perform the following steps to use the SourceMeter to measure voltage or current:

1. Select source-measure functions.

   Measure voltage only (voltmeter) — Press SOURCE I to select the I-Source, and press MEAS V to select the voltage measurement function.

   Measure current only (ammeter) — Press SOURCE V to select the V-Source, and press MEAS I to select the current measurement function.

2. Set source and compliance levels.

   Use the editing procedure provided in step 2 of the "Basic source-measure procedure" to edit the source and compliance levels as follows:

   A. Select the lowest source range and set the source level to zero (00.0000μA or 000.000mV).

   B. Set compliance to a level that is higher than the expected measurement.

CAUTION **When using the SourceMeter as a voltmeter, V-Compliance must be set higher than the voltage that is being measured. Failure to do this could result in instrument damage due to excessive current that will flow into the SourceMeter.**

3. Select range.

   Use the RANGE ▲ and ▼ keys to select a fixed measurement range that will accommodate the expected reading. Use the lowest possible range for best accuracy.

   When measuring current, AUTO range can instead be used. The SourceMeter will automatically go to the most sensitive range. When measuring voltage, DO NOT use AUTO range (see the following CAUTION).

CAUTION **When using the SourceMeter as a voltmeter only, DO NOT use AUTO range and NEVER select a measurement range that is below the applied signal level. For these conditions, high current will be drawn from the external source. This high current could damage the external source or test circuit.**

4. Connect voltage or current to be measured.
   Connect the DUT to the SourceMeter as shown in Figure 2-19. This is a 2-wire measurement and requires that local sensing be selected. Refer to Figure 2-11 for details on the Measure Only configurations.
5. Turn output on.
   Press the ON/OFF key to turn the output on.
6. Take reading from display.
7. When finished, turn output off.

Sink operation

When operating as a sink (V and I have opposite polarity), the SourceMeter is dissipating power rather than sourcing it. An external source (i.e., battery) or an energy storage device (i.e., capacitor) can force operation into the sink region.

For example, if a 12V battery is connected to the V-Source (In/Out HI to battery high) that is programmed for +10V, sink operation will occur in the second quadrant (source +V and measure -I). See "Battery charging/discharging" for details on charging and discharging batteries.

CAUTION **When using the I-Source as a sink, ALWAYS set V-Compliance to a level that is higher than the external voltage level. Failure to do so could damage the instrument due to excessive current that will flow into the SourceMeter.**

NOTE *The sink operating limits are shown in Figure 2-3 (quadrants II and IV). The operating boundaries shown are only valid if the ambient temperature is 30°C or less. See "Operating boundaries" for details.*

Above 30°C, high power operation could overheat the SourceMeter, causing the output to turn off. See "Overheating protection" and "Overheating prevention power equations" for details.

Battery charging/discharging

When charging a battery, the SourceMeter is operating as a source. When discharging a battery, the SourceMeter is operating as a sink. It is recommended that the V-Source be used to charge and discharge batteries. Perform the following steps for both charging and discharging:

1. Connect Input/Output HI to the positive (+) terminal of the battery and Input/Output LO to the negative (-) terminal of the battery.
2. Configure the SourceMeter to source voltage and measure current.
3. Set I-compliance to the current level at which the battery is to be charged or discharged.
4. Select an appropriate current measurement range or use AUTO range.

Battery charging — To charge the battery, program the SourceMeter to output a voltage that is equivalent to the voltage rating of the battery. For example, to charge a 10V battery, set the SourceMeter to source 10V. As the battery fully charges, current will decrease until it reaches zero or near zero (battery charged).

Battery discharging — To discharge the battery, program the SourceMeter to output 0V. In this configuration, the SourceMeter operates as a sink to discharge the battery. Current from the battery flows into the HI terminal of the SourceMeter resulting in negative current measurements. As the battery discharges, current will gradually decrease until it reaches zero (battery discharged).

NOTE *When using the V-Source to charge and discharge batteries, use the HIGH-IMPEDANCE output-off state. This output-off state opens the output relay when the OUTPUT is turned off. This open circuit condition keeps the external battery from discharging while the output is off.*

CAUTION **If using the I-Source to charge and/or discharge batteries, the following precautions must be observed. Failure to observe these precautions could result in damage to the SourceMeter that is not covered by the warranty.**

Make sure the external voltage NEVER exceeds the voltage compliance setting of the I-Source. This will cause excessive current to be drawn from the external battery or source.

Make sure the output off state of the I-Source is set for HIGH-IMPEDANCE. This setting opens the output relay when the OUTPUT is turned OFF. With the NORMAL output off state selected, turning the output off sets voltage compliance to zero. This 0V compliance condition will cause excessive current to be drawn from the external battery or source. See "Configure operate" in Section 3 to select the high-impedance output off state.

Sweep operation

The following information explains the various sweep types that are available, explains how to select and configure a sweep, and provides a general procedure for running a sweep from the front panel. Note that sweep test data is automatically stored in the buffer.

Sweep types

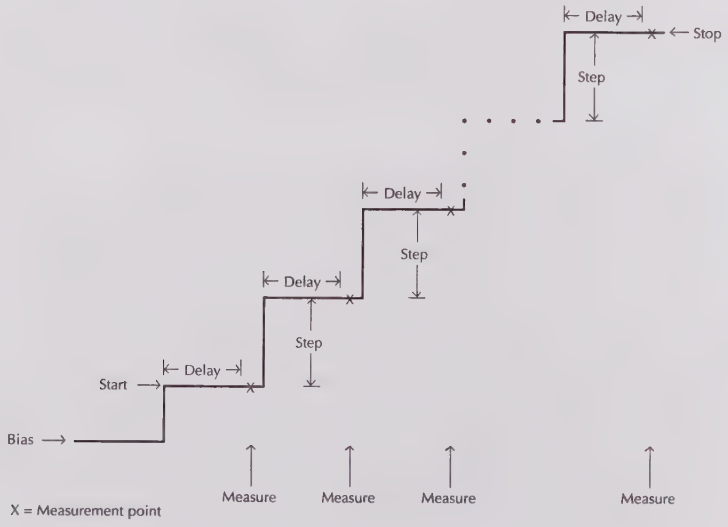
The four basic sweep types are described as follows:

Linear staircase sweep

As shown in Figure 2-23, this sweep steps from a start source value to an ending (stop) source value. Programmable parameters include the start, stop, and step source levels.

When this sweep is triggered to start, the output will go from the bias level to the start source level. The output will then change in equal steps until the stop source level is reached. With trigger delay set to zero, the time duration at each step is determined by the source delay and the time it takes to perform the measurement (NPLC setting).

Figure 2-23
Linear staircase sweep



Logarithmic staircase sweep

This sweep is similar to the preceding sweep. The steps, however, are done on a logarithmic scale as shown in the example sweep in Figure 2-24. This is a 5-point log sweep from 1 to 10V.

The programmable parameters for a log sweep include the start and stop levels and the number of measurement points for the sweep. The specified start, stop, and point parameters determine the logarithmic step size for the sweep. Step size for the sweep in Figure 2-24 is calculated as follows:

$$\text{Log Step Size} = \frac{\log10\,(\text{stop}) - \log10\,(\text{start})}{\text{Points} - 1}$$

$$= \frac{\log10\,(10) - \log10\,(1)}{5-1}$$

$$= \frac{(1-0)}{4}$$

$$= 0.25$$

Thus, the five log steps for this sweep are 0, 0.25, 0.50, 0.75, and 1.00. The actual V-Source levels at these points are listed as follows. The V-Source level is the anti-log of the log step.

Measure point	Log step	V-Source level (volts)
Point 1	0	1
Point 2	0.25	1.7783
Point 3	0.50	3.1623
Point 4	0.75	5.6234
Point 5	1.0	10

When this sweep is triggered to start, the output will go from the bias level to the start source level (1V) and sweep through the symmetrical log points. With trigger delay set to zero, the time duration at each step is determined by the source delay and the time it takes to perform the measurement (NPLC setting).

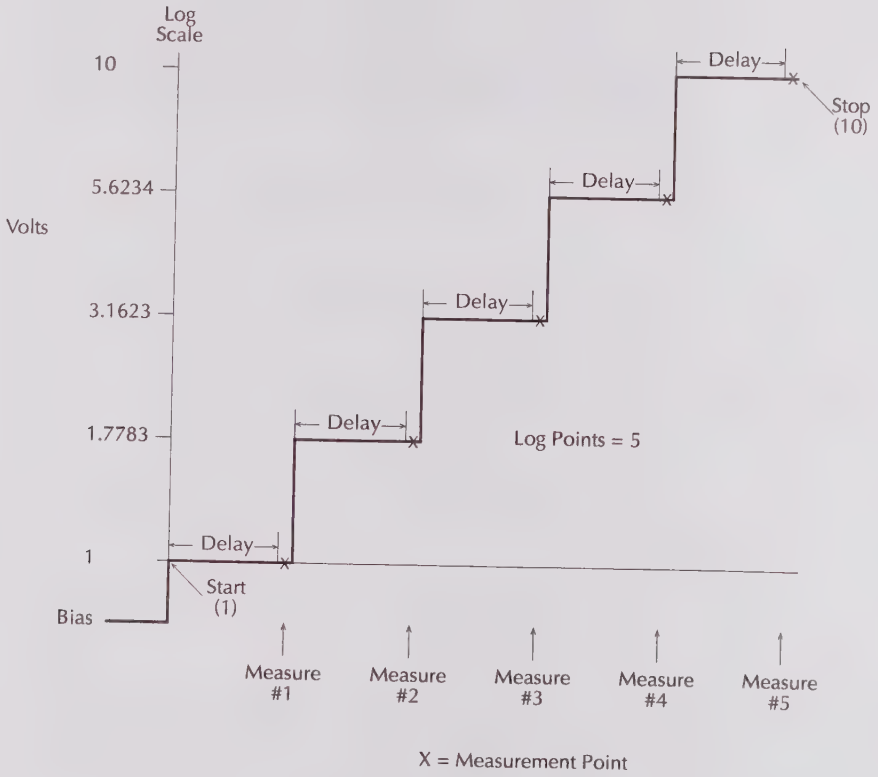


Figure 2-24
Logarithmic staircase sweep (example 5-point sweep from 1 to 10 volts)

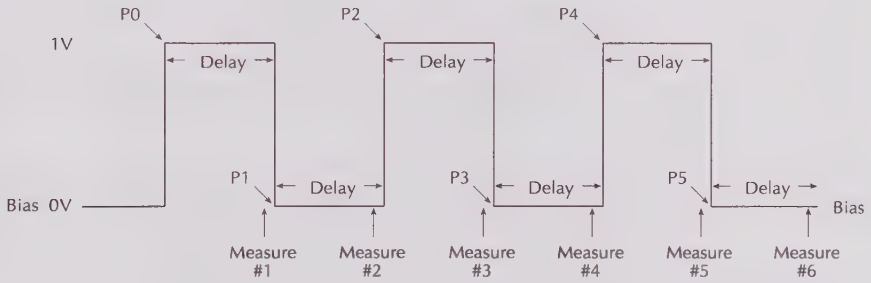
Custom sweep

This sweep allows you to configure a customized sweep. Programmable parameters include the number of measurement points in the sweep and the source level at each point.

When this sweep is started, the output will go from the bias level to the first source-measure point in the sweep. The sweep will continue through the source-measure points in the order that they were programmed and stop after the last source-measure point. With trigger delay set to zero, the time duration at each step is determined by the source delay and the time it takes to perform the measurement (NPLC setting).

The custom sweep can be configured to provide a 50% duty cycle pulse sweep. Figure 2-25 shows a pulse sweep that provides three 1V pulses on a 0V bias level. This pulse sweep is configured by specifying six points for the custom sweep. The specified voltage levels at points P0, P2, and P4 are 1V, and the specified voltage levels at points P1, P3, and P5 are 0V. Six measurements are performed for this sweep, three at 1V and three at 0V.

Figure 2-25
Custom pulse sweep



Source memory sweep

For a Source Memory Sweep, you save (up to 100) setup configurations in memory. When the sweep is performed, the setup at each memory point is recalled. This allows multiple functions and math expressions to be used in a sweep. For example, the first point in a Source Memory Sweep may source voltage and measure current, the next point may source current and measure voltage, the third point may source voltage and measure voltage, and the last point may use a math expression.

Sweep configuration — The user specifies the number of memory location points to sweep and where to start the sweep. For example, you can specify a six point sweep that starts at memory location 98. When the sweep is started, the setups at memory location points 98, 99, 100, 1, 2, and 3 are recalled. When sweeping past point 100, the sweep automatically wraps back to memory location point 1. These and other components of the sweep are configured from the CONFIGURE SWEEPS menu (see "Select and configure sweep").

Saving setups — SourceMeter setups are saved in memory from the SAVESETUP (SOURCE MEMORY) option of the MAIN MENU. Perform the following steps to save setups in memory for a Source Memory Sweep:

1. Configure the SourceMeter for the desired source, measure, and/or math expression operation.
2. Press MENU to display the MAIN MENU:
   - Select SAVESETUP.
   - Select SOURCE MEMORY.
   - Select SAVE.
   - Use the ▲ and ▼ keys, and the cursor keys (◄ and ►) to display the desired memory location, and press ENTER.
   - Use the EXIT key to back out of the menu structure.
3. Configure the SourceMeter for the next point in the sweep, and repeat Step 2 to save that setup in the next memory location.
4. Repeat Step 3 for all points in the sweep.

NOTE *See "Main menu" in Section 3 for details on using the Main Menu.*

Sweep branching — When using a Source Memory Sweep when performing limit tests, the normal sequence of sweep memory points can be changed. This is useful when, based on the results of an initial test, a different set of tests are needed.

The sweep can branch to a specified memory location point, or simply proceed to the next memory location in the list. When a memory location is specified, the sweep will branch to that memory location if the test is successful (PASS condition). If not successful (FAIL condition), the sweep proceeds to the next memory location in the list. With NEXT selected (the default), the sweep proceeds to the next memory location in the list regardless of the outcome of the test (PASS or FAIL condition).

Diode testing

An application that could use branching is diode testing. Because a diode is polarity sensitive, you normally have to be careful when installing it in the component handler. Installing the diode one way forward biases it, and installing it the other way reverse biases it. Memory sweep branching can eliminate this installation problem.

If, for example, your test requires that the diode be forward biased, you can configure the compliance limit test (LIMIT 1) to fail if out of compliance. This fail condition would indicate that the diode is forward biased, and the memory sweep will proceed to the next source memory location to perform the source-measure operation. If, however, the diode is installed backwards, the compliance limit test will PASS (in compliance). The pass condition will cause the sweep to branch to a memory location where the polarity of the source is reversed, again forward biasing the diode for the source-measure operation.

This branching technique simplifies installation of the diode in the component handler because polarity is no longer a concern. If the diode is installed backwards, the sweep will branch to a memory location that reverses source polarity.

Caution must be used when branching since infinite memory loops can inadvertently be created. Also, a single Source Memory Sweep will always sweep the number of points specified, regardless of how many branches were taken.

Memory sweep branching option is set from the PASS (SRC MEM LOC) item of the CONFIG LIMITS MENU (see "Limit testing" and "Configure limit tests" for details).

Select and configure sweep

The sweep configuration menu is structured as follows. Note that bullets indicate the primary items of the sweep menu and dashes indicate the options of each menu item. Using the "Rules to navigate menus", go through the following menu to select and configure the desired sweep.

CONFIGURE SWEEPS menu:
Press CONFIG and then SWEEP to display the sweep configuration menu.

- TYPE — Use this menu item to select the type of sweep:
  - STAIR — When the linear staircase sweep is selected, you will be prompted to enter the START, STOP, and STEP levels.
  - LOG — When the logarithmic staircase sweep is selected, you will be prompted to enter the START and STOP levels, and specify the number of measurement points.
  - CUSTOM — With the custom sweep selected, you specify the number of measurement points (# POINTS) in the sweep and the source level at each point (ADJUST POINTS). With the INIT option, you can set a consecutive range of measurement points in the sweep to a specific level. For example, assume that for a 20-point custom voltage sweep (# POINTS = 20), you want points 10 through 15 to be set for 1V. After selecting the INIT option, set the VALUE to +1.000000V, set the START PT to 10, and set the STOP PT to 15.
  - SRC MEMORY — With the Source Memory Sweep selected, you specify the memory location START point to start the sweep (1 is the default) and the number of memory location points (# POINTS) in the sweep. When configured to sweep past point 100, the sweep automatically wraps around to point 1.
- SWEEP COUNT — Use this menu item to specify how many sweeps to perform:
  - FINITE — Use this option to enter a discrete number of sweeps to perform with the results stored in the data store buffer. The maximum number of finite sweeps that can be performed is determined as follows:

    maximum finite sweep count = 2500 / # points in sweep
  - INFINITE — Select this option to continuously repeat the configured sweep. Use the EXIT key to stop the sweep. Data is not stored in the buffer.
- SOURCE RANGING — Use this menu item to control source ranging:
  - BEST FIXED — With this option, the SourceMeter will select a single fixed source range that will accommodate all of the source levels in the sweep. For example, if the minimum and maximum source levels in the sweep are 1V and 30V, the 60V source range will be used.
  - AUTO RANGE — With this option, the SourceMeter will select the most sensitive source range for each source level in the sweep. For example, for a 1V source level, the 2V source range will be used, and for a 30V source level, the 60V source range will be used. Note that the range changing process of AUTO RANGE may cause transients in the sweep. If these transients cannot be tolerated, use the BEST FIXED source range.

– FIXED — With this option, the source remains on the range presently on when the sweep is started. For sweep points that exceed the source range capability, the source will output the maximum level for that range. For example, if the source is on the 2V range when the sweep is started, it will remain on the 2V range for the entire sweep. If the configured sweep points are 1V, 2V, 3V, 4V, and 5V, the sweep will be 1V, 2V, 2.1V, 2.1V, and 2.1V.

Set delay

Generally, the time duration spent at each step (or point) of a sweep consists of the source delay and the time it takes to perform the measurement (NPLC setting).

The source delay is part of the SDM cycle and is used to allow the source to settle before the measurement is made (see "Operation overview; source-delay-measure cycle" for details).

The total time period of the source delay could include an auto-delay and/or a user programmed delay. With auto-delay enabled, 1msec of delay is used. The user programmable source delay adds 0.0000 to 999.9999 seconds of delay (see "Source configuration" in Section 3 to set these delays).

Additional delay for a sweep is available by using the trigger delay. This user-specified delay (0.0000 to 999.9999 seconds) occurs before each SDM cycle (device action) of the sweep. Thus, the trigger delay is executed before each new source-point in the sweep (see "Trigger model" in Section 3). See "Configure triggering" in Section 3 to set trigger delay.

Perform sweep

Perform the following steps to run a sweep:

NOTE *The following procedure assumes that the SourceMeter is already connected to the DUT as explained in "Connections."*

1. Configure source-measure functions.

   Configure the SourceMeter for the desired source-measure operations by performing steps 1 through 3 of the "Basic source-measure procedure".

   The source level you set becomes the bias level for the sweep. When turned on, the output will maintain this bias level until the sweep is started. Typically, 0V or 0A is used as the bias level.

   If using a fixed measurement range, make sure it can accommodate every measurement point in the sweep. Otherwise, use autoranging.

2. Configure sweep and set delay.

   Select and configure the sweep as explained in "Configure sweep" and "Set delay."

3. Turn output on.

   Press the ON/OFF key to turn the output on (red OUTPUT indicator turns on). The SourceMeter will output the programmed bias level.

4. Run sweep.

   To run the sweep, press the SWEEP key. After the sweep is completed, turn the output off by pressing the ON/OFF key.

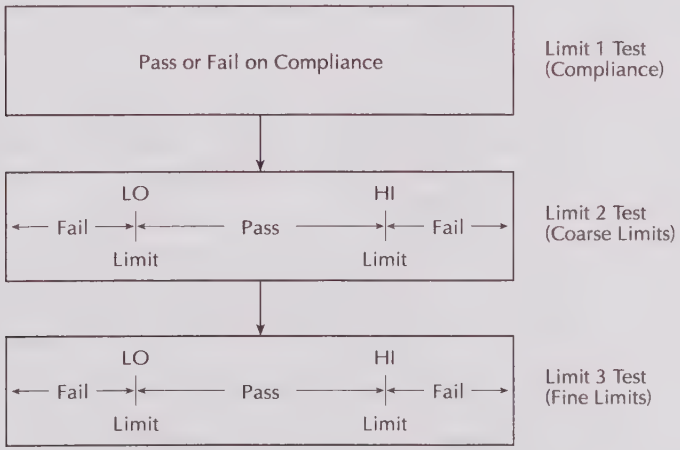
5. Read buffer.

   Use the RECALL key to access the source-measure readings stored in the buffer. Use the TOGGLE to display statistical information (see "Data store" in Section 3).

Limit testing

As shown in Figure 2-26, there are three limit tests that can be performed on a DUT. A test is only performed if it is enabled. Thus, you can perform one, two, or all three tests. The tests are always performed in the order shown in the drawing.

Figure 2-26
Limit tests



Limit 1 Test — This test checks the compliance state of the SourceMeter. It uses the programmed compliance as the test limit. At or above the programmed limit, the instrument is in compliance. Below the limit, the instrument is not in compliance.

For example, assume you want to "pass" resistors that are below 1kΩ. To do this set the I-Source to output 1mA at a compliance limit of 1V, and configure the test to fail on compliance. If, for example, the resistor under test is 750Ω, output voltage will be 0.75V (1mA × 750Ω = 0.75V). Since the output voltage is below the 1V limit, the test passes. If the resistor is 1kΩ (or more), output voltage will be 1V (1mA × 1kΩ = 1V). Since the 1V limit is reached, which places the SourceMeter in compliance, the test fails.

The Limit 1 test can be used to determine the polarity of a device, such as a diode. By using this test with a Source Memory Sweep, you can branch to a different setup at a specified memory location when the device is installed backwards. See "Source memory sweep - sweep branching" in "Sweep operation" for details on "Diode testing."

Limit 2 and Limit 3 Tests — These tests are used to determine if a DUT is within specified high and low limits. Typically, the Limit 2 test is used to test for "coarse" tolerance limits, and the Limit 3 test is used for "fine" tolerance limits.

For example, assume you want to sort resistors into three groups: 1%, 5%, and >5% tolerance. To do this, configure Limit 2 test for 5% HI and LO limits, and Limit 3 test for 1% HI and LO limits. If Limit 2 fails, the handler places the DUT in the bin labeled >5%. If Limit 2 passes, Limit 3 test is run. If Limit 3 fails, the DUT is placed in the bin labeled 5%. If Limit 3 passes, the handler places the DUT in the bin labeled 1%.

Binning — Even though no additional equipment is required to perform limit tests on the DUT, the SourceMeter is typically used with a component handler to perform binning operations. The binning system can be further automated by adding a scanner. With the use of a scanner, the tests can be repeated (cycled) to test individual elements of a single package (i.e., resistor network). See "Binning systems" for more information on using component handlers and scanners to perform binning operations.

Operation overview

Limits operation is detailed by the flowchart in Figure 2-27. A test is only performed if it is enabled. If disabled, operation proceeds to the next test. The following assumes all three limit tests are enabled and the digital output of the SourceMeter is connected to a component handler for DUT binning (see "Binning systems"). If a handler is not used, ignore digital input/output (handler interface) actions.

With the limit tests properly configured, turn the SourceMeter output on and press the LIMITS key. The testing process will start when the component handler sends the SOT (start-of-test) strobe pulse to the SourceMeter. Note that if a handler is not used, testing will start when LIMITS is pressed. Pressing LIMITS a second time terminates the testing process.

As shown in the flowchart, limit tests are performed after a measurement conversion.

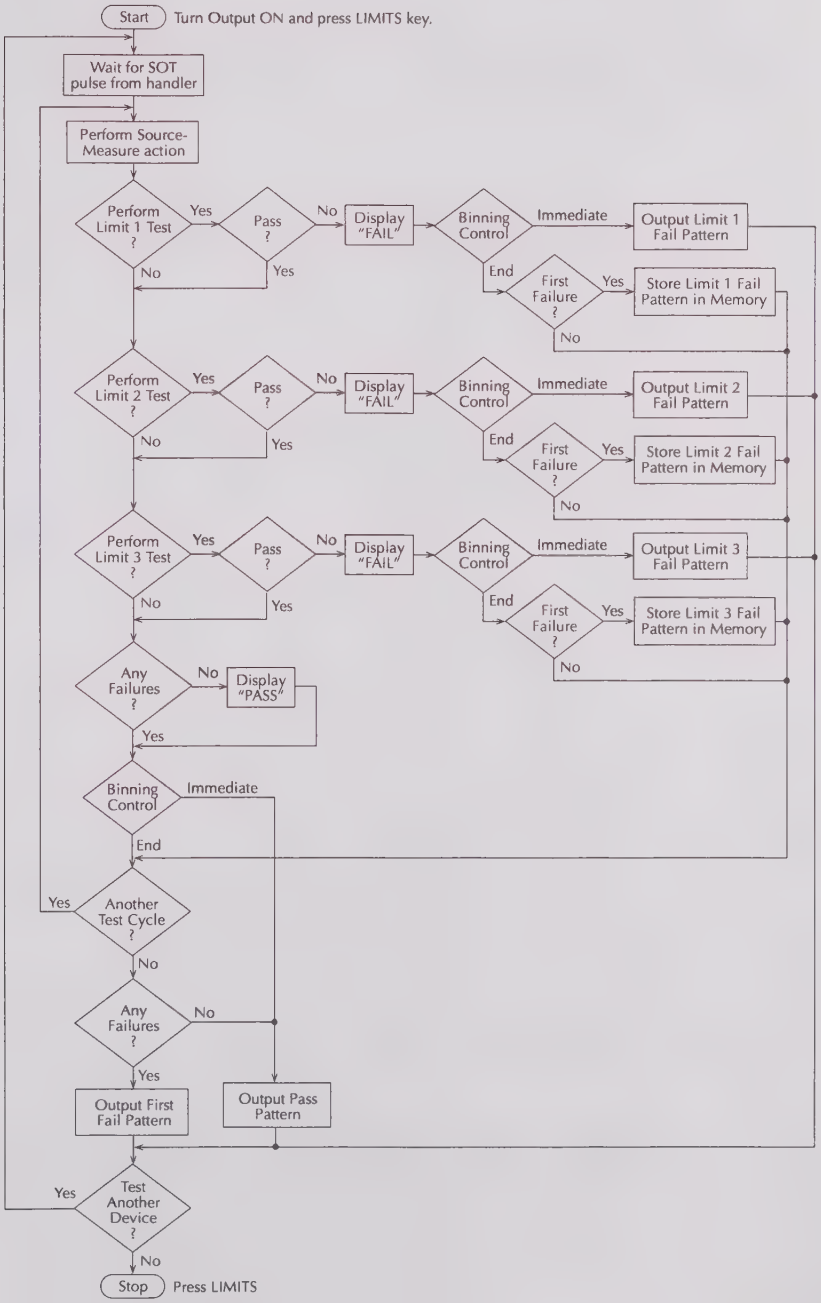
Binning control

The binning control selection determines when the testing process stops and the appropriate binning operation that occurs. There are two types of binning control: immediate and end.

Immediate Binning — Use immediate binning when you want to stop all testing after the first failure occurs. Any pending tests will be canceled, and the DUT will be placed in the bin assigned to that test failure. If no failures occur, all enabled tests will be performed, and the DUT will be placed in the assigned "pass" bin.

Using a sweep with immediate binning lets you test different devices at different source levels. For example, assume a 3-point linear sweep at 1V, 2V, and 3V step levels. The first DUT is tested at 1V, the second DUT is tested at 2V, and the third DUT is tested at 3V.

Figure 2-27
Limits operation



End Binning — End binning allows a sweep to finish before performing the binning operation. In the event of a failure, the first test failure determines the bin assignment.

Using a sweep with end binning lets you test a device at different source levels. For example, assume a 3-point list sweep at 1.1V, 2.2V, and 3.3V source levels. Limit testing will be performed at each source level. After the completion of the three test cycles, the DUT is placed in the appropriate bin.

Adding a scanner to the system lets you test each element of a multi-element device (i.e., resistor network). For example, the previous 3-point list sweep can be used to test a 3-element resistor network. The first test cycle (using the 1.1V source level) tests the first element of the network. The second test cycle (2.2V) tests the second element of the network, and last test cycle (3.3V) tests the third element. After the three test cycles are finished, the resistor network is placed in the appropriate bin.

Pass condition

For this discussion, assume that all limit tests pass. After the three limit tests pass, the "PASS" message is displayed, and operation drops down to the Binning Control decision block.

Immediate binning — For immediate binning, the testing process stops. The SourceMeter outputs the pass pattern to the component handler to perform the binning operation.

End binning — For end binning, operation drops down to the Another Test Cycle? decision block. If programmed to perform additional tests (i.e., sweep) on the DUT package, operation loops back up to perform the next source-measure action. After all programmed test cycles are successfully completed, the SourceMeter outputs the pass pattern to the component handler to perform the binning operation.

If configured to test another DUT package, operation loops back to the top of the flowchart and waits for the SOT (start of test) pulse from the component handler.

Fail condition

When a failure occurs, the FAIL message is displayed, and operation proceeds to the Binning Control decision block.

Immediate binning — For immediate binning, the testing process is terminated and the fail pattern for that particular failure is sent to the component handler to perform the binning operation.

End binning — For end binning, the fail pattern for the first failure is stored in memory and operation proceeds to the Another Test Cycle? decision block. If programmed to perform additional tests (i.e., sweep) on the DUT package, operation loops back up to perform the next source-measure action. Note that when a failure occurs, subsequent tests in the test cycle are not performed.

After all programmed test cycles are completed, the SourceMeter outputs the fail pattern stored in memory. This reflects the first failure that occurred in the testing process for the device package. The component handler places the DUT in the appropriate bin.

If configured to test another DUT package, operation loops back to the top of the flowchart and waits for the SOT (start-of-test) pulse from the component handler.

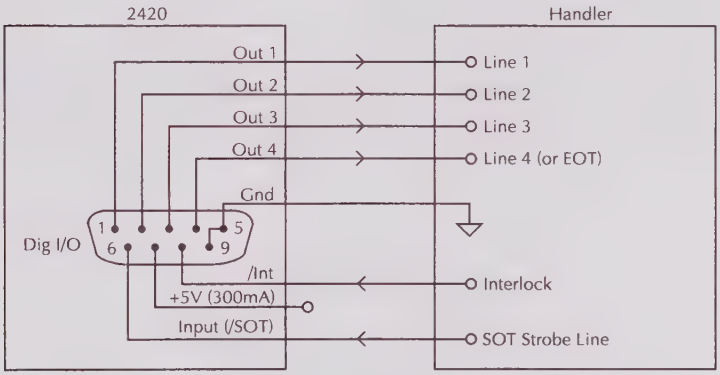
Binning systems

The SourceMeter can be used with a component handler to perform binning operations on DUT packages. With this system, you can test single-element devices (i.e., resistor). Adding a scanner to the system allows binning operations on multiple-element DUT packages.

Handler interface

The SourceMeter is interfaced to a handler via the Digital I/O port as shown in Figure 2-28. The I/O port has four lines for output signals and one line for input signals. The output lines are used to send the test pass/fail signal(s) to the handler to perform the binning operation.

Figure 2-28
Handler interface connections



The input line (/SOT) of the Digital I/O is used to control the start of the testing process. When START TEST is the selected arm event for the arm layer of the trigger model, the testing process will start when the /SOT line is pulled low. With the IMMEDIATE arm event selected, the testing process will start as soon as the LIMITS key is pressed (assuming the output is on). See "Trigger operations" in Section 3 for details on trigger model configuration.

When used by a handler, the /SOT line is kept high while it is in a not ready condition. When the handler is ready (DUT properly position in the handler), it pulls the /SOT line low to start the test.

The /Int line of the Digital I/O can be used if the component handler is equipped with an interlock switch. With proper use of the interlock, power is removed from the DUT when the lid of the handler is opened. See "Digital I/O port and safety interlock" in Section 3 for operation details on the interlock.

These digital I/O lines are available at the DB-9 connector on the rear panel of the SourceMeter. A custom cable using a standard female DB-9 connector is required for connection to the SourceMeter.

The SourceMeter can be used with either of the two basic types of handlers. When used with a Category Pulse Handler, the SourceMeter pulses one of the four handler lines. The handler then places the DUT into the bin assigned to the pulsed line.

When used with a Category Register Handler, the SourceMeter outputs a bit pattern to three handler lines. After the SourceMeter sends the end-of-test (EOT) strobe pulse to the fourth handler line, the handler places the DUT into the bin assigned to that bit pattern.

Two basic binning systems are shown in Figures 2-29 and 2-30. Both systems require a handler to physically place the device packages in the appropriate bins. The handler is controlled by the SourceMeter via the digital I/O port.

Single-element device binning

Figure 2-29 shows a basic binning system for single-element devices (i.e., resistors). After all programmed testing on the DUT is completed, the appropriate digital output information is sent to the component handler, which then places the DUT in the appropriate bin. The component handler selects the next DUT and the testing process is repeated.

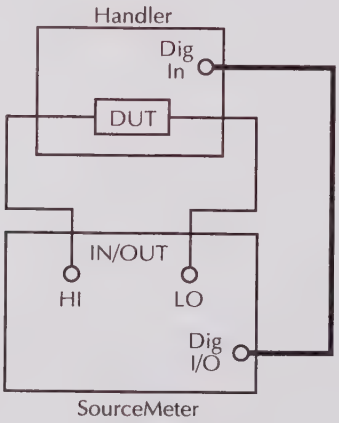
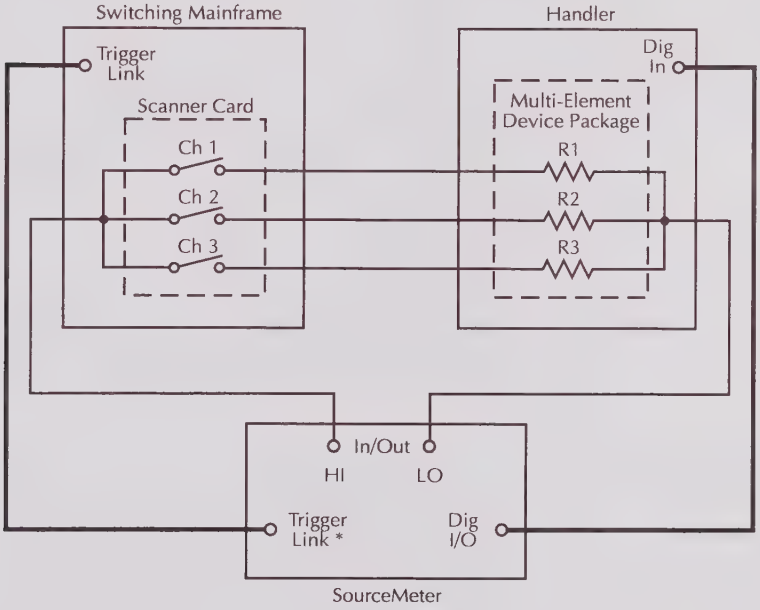


Figure 2-29
Binning system – single element devices

Multiple-element device binning

Figure 2-30 shows a basic binning system to test three-element resistor networks. Note that this system requires a scanner card that is installed in a switching mainframe. Scanner card switching is controlled through the Trigger Link. End binning control is required for this test system.

Figure 2-30
Binning system – multiple element devices



* Trigger layer configured to output trigger pulse after each measurement.

Trigger operations for the scanner and SourceMeter must be configured appropriately for this test. In general, the scanner must be configured to scan three channels, and the SourceMeter must be configured to perform a 3-point sweep and output a trigger to the scanner after each measurement. See "Trigger operations" for details.

When the testing process is started, Ch 1 of the scanner card closes, and R1 is measured. Two events occur concurrently after the measurement is completed; R1 is tested, and the SourceMeter sends a trigger pulse to the switching mainframe causing Ch 1 to open and Ch 2 to close. Assuming no failure, a measurement is then performed on R2. While R2 is being tested, Ch 2 opens and CH 3 closes. Again assuming no failure, a measurement is performed on R3 and it is then tested. Assuming that all tests on all three resistors passed, the device package is placed in the pass bin.

If any of the resistors in the network fails a test, the FAIL message is displayed, and the digital output information for the first failure is stored in memory (assuming that END binning control is selected). After the sweep is completed, the SourceMeter sends the output pattern stored in memory. This is the output pattern for the first test failure. The component handler places the DUT package into the bin assigned to that particular failure.

The handler selects the next resistor network, and the testing process is repeated.

Digital output clear pattern

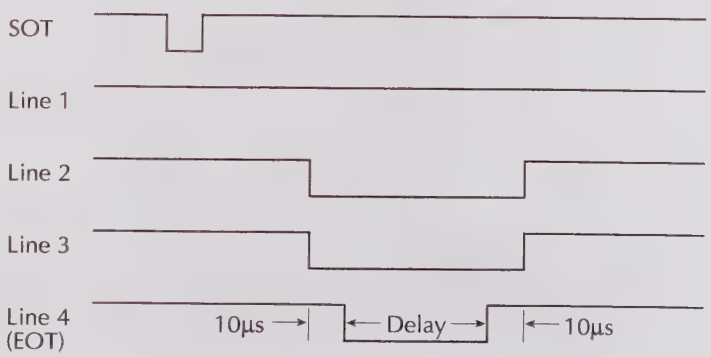
After every binning operation, the digital output needs to be reset to a clear pattern, which serves as a "no action" condition for the component handler.

The SourceMeter can be programmed to automatically clear the digital output after the pass or fail pattern is sent. With auto-clear, you must specify the required pulse width (delay) for the pass or fail pattern. When not using auto-clear, you must return the digital output to its clear pattern from the DIGOUT option of the GENERAL MENU (see "Main Menu").

Auto-clear, the clear output pattern, and the pulse width for the pass/fail pattern are set from the DIGOUT CLEAR selection of the Limits Configuration Menu.

Auto-Clear Timing — The following example timing diagram and discussion explain the relationship between the digital output lines for auto-clear.

Figure 2-31
Digital output auto-clear timing example



Initially, the four digital output lines are cleared (in this case, they are all set high). Limit tests start when the start-of-test (SOT) pulse is received from the component handler. When the testing process is finished, the pass or fail pattern is applied to the digital output. As shown in the diagram, lines 2, 3, and 4 go low while line 1 remains high.

The pulse width (delay) of the pass/fail pattern can be set from 0 to 60sec (100µsec resolution) as required by the component handler. Note that the delay specifies the pulse width of line 4. The pulse width of lines 1, 2, and 3 is actually 20µsec longer. Line 4 is skewed because it is used as the end-of-test (EOT) strobe by category register component handlers. Lines 1, 2, and 3 establish the bit pattern and then 10µsec later the SOT strobe "tells" the handler to read the bit pattern and perform the binning operation. This 10µsec offset is used to make sure the correct bit pattern is read by the handler.

After the pass/fail is read by the handler, the digital output returns to the clear pattern.

Category Pulse Component Handler — When using this type of handler, the SourceMeter pulses one of the four handler lines when a pass or fail condition occurs. The handler then places the DUT in the bin assigned to that pulsed line. When interfacing to this type of handler, a maximum of four component handler bins are supported.

If the handler requires low-going pulses, then the four digital output lines of the SourceMeter will initially have to be set high. This initial HI, HI, HI, HI clear pattern on the output lines represents a "no action" condition for the handler since it is waiting for one of the lines to go low. A line goes low when the defined fail or pass pattern sets it low. For example, if you want a particular test failure to pulse line #4 of the handler, the defined fail pattern has to be HI, HI, HI, LO. When the failure occurs, line #4 will be pulled low, and the DUT will be placed in the bin assigned to that pulsed line.

If the handler requires a high-going pulse, the four digital output lines of the SourceMeter must initially be set low. The LO, LO, LO, LO clear pattern represents the "no action" condition for the handler. When one of those lines are pulled high by a defined pass or fail bit pattern (i.e., LO, LO, LO, HI), the DUT will be placed in the bit assigned to that pulsed line.

Category Register Component Handler — When using this type of handler, the SourceMeter sends a bit pattern to three handler lines when a pass or fail condition occurs. This bit pattern determines the bin assignment for the DUT. With the pass/fail pattern on the output, line #4 is then pulsed. This EOT (end-of-test) pulse latches the bit pattern into the register of the handler that then places the DUT in the assigned bin. When interfacing to this type of handler, a maximum of eight component handler bins are supported.

If the handler requires a low-going EOT pulse, line #4 of the digital output must initially be set high. When the EOT line is pulsed low, the binning operation occurs. When using the CONFIG LIMITS MENU to define pass/fail bit patterns, line #4 must be set low. If, for example, the required fail pattern by the handler is HI, LO, HI, then you must define the fail pattern of the test to be HI, LO, HI, LO. When the test fails, the HI, LO, HI bit pattern is sent to the handler. When line #4 goes LO, the bit pattern is latched into the register of the handler, and the binning operation occurs.

Conversely, if the handler requires a high-going EOT pulse, the EOT line of the digital output must initially be set low (off). When the EOT line is pulsed high, the binning operation occurs.

NOTE *Bit patterns for the various pass and fail conditions are configured from the CONFIG LIMITS MENU (see "Configure limit tests").*

Configure limit tests

Press CONFIG and then LIMITS to display the CONFIG LIMITS MENU. The limits configuration menu is structured as follows. Note that bullets indicate the primary items of the limit menu and arrows point to the options of each menu item. Configure the limit tests using the "Rules to navigate menus."

- LIMIT 1 — Use this menu item to control and set the fail mode for Limit 1 test:
  - CONTROL — Use to ENABLE or DISABLE the test.
  - FAIL MODE — Use to select the fail mode for Limit 1 test. With IN COMPLIANCE selected, the test will fail when the SourceMeter is in compliance. With NO COMPLIANCE selected, the test will fail when not in compliance. Also use to specify the digital output bit pattern for Limit #1 test failure.
- LIMIT 2 — Use this menu item to control, set limits, and define output bit patterns for Limit 2 test:
  - CONTROL — Use to ENABLE or DISABLE the test.
  - LOLIM — Use to set the low limit and specify the "fail" bit pattern.
  - HILIM — Use to set the high limit and specify the "fail" bit pattern.
- LIMIT 3 — Use this menu item to control, set limits, and define output bit patterns for Limit 3 test:
  - CONTROL — Use to ENABLE or DISABLE the test.
  - LOLIM — Set the low limit and specify the "fail" bit pattern.
  - HILIM — Set the high limit and specify the "fail" bit pattern.
- PASS — Use this menu item to dictate actions upon a PASS condition:
  - DIGIO PATTERN — Use this option item to define the digital output bit pattern for the "all tests pass" condition.
  - SRC MEM LOC — Use this option with a Source Memory Sweep to select the next memory location point in the sweep when the PASS condition occurs. If NEXT is selected, the next point in the sweep list will be selected. You can also branch to a different point in the sweep by specifying the memory LOCATION# (1 to 100).
- DIGOUT CLEAR — Use this menu item to ENABLE or DISABLE auto-clear for the digital output. After enabling auto-clear, you will be prompted to set the pass/fail pattern pulse width (delay; 0 to 60sec with 100µsec resolution). After setting delay, you will be prompted to set the digital output clear pattern.
- DIGOUT BIN CTRL — Use this menu item to specify when to end the testing process and place the pass or fail pattern on the digital output.
  - IMMEDIATE — With this selection, the testing process will stop after the first failure and place the fail pattern on the digital output. If none of the three tests fail, the pass pattern will be placed on the output, and the testing process will stop.
  - END — With this selection, the testing process will continue until the programmed sweep is completed, regardless of how many failures occur. This allows multi-element devices (i.e., resistor networks) to be tested. After testing is finished, the bit pattern for the first failure is placed on the output. If all tests pass, the pass pattern will instead be placed on the output.

Perform limit tests

Perform the following steps to run limit tests:

1. Configure test system.

   As previously explained, your test system could be as simple as connecting a DUT to the SourceMeter (see "Connections") or could employ the use of a handler for binning operations. Adding a scanner to the test system allows you to test multi-element devices (such as resistor networks). Make sure that the Digital I/O is configured appropriately for the handler you are using.

2. Configure source-measure functions.

   Configure the SourceMeter for the desired source-measure operations by performing steps 1 through 3 of the "Basic source-measure procedure."

3. Configure limit tests.

   Select and configure the limit tests as explained in "Configure limit tests."

4. Turn output on.

   Press the ON/OFF key to turn the output on (red OUTPUT indicator turns on). The SourceMeter will output the programmed bias level.

5. Start testing process.

   To enable the limit tests, press the LIMITS key. If the /SOT line of the Digital I/O is being used by a handler, the testing process will not start until the handler sends a low-going pulse. Otherwise, the testing process will start when LIMITS is pressed.

NOTE *The "PASS" and "FAIL" messages indicate the status of each test cycle, with the following exceptions:*

- *When in the NORMAL, HIGH IMPEDANCE or GUARD output-off state, the "OFF" message is displayed. The pass and fail conditions will be displayed as "P OFF" and "F OFF" respectively.*
- *When in the ZERO output-off state, the "ZER" message is displayed. The pass and fail conditions will be displayed as "P ZER" and "F ZER" respectively.*
- *If the source reaches the OVP (over-voltage protection) limit, the "OVP" message will be displayed. The pass and fail conditions will be displayed as "P OVP" and "F OVP" respectively.*

6. Stop testing process.

   The testing process can be terminated at any time by again pressing LIMITS. When using a handler, the testing process will stop after the last DUT is tested.

Math (FCTN) operations

The SourceMeter has built-in math functions to calculate the following:

- Power
- Offset Compensated Ohms
- Varistor Alpha
- Voltage Coefficient
- Percent Deviation

The Power and Percent Deviation math functions use a single voltage and/or current measurement to perform the calculation. The Offset Compensated Ohms, Varistor Alpha, and Voltage Coefficient math functions require 2-point measurements to perform a calculation.

Power

This math function calculates power using the measured voltage and measured current values as follows:

$$\text{Power} = V \times I$$

where: V = measured voltage
I = measured current

Offset compensated Ω

The presence of thermal EMFs (V_{EMF}) can adversely affect low-resistance measurement accuracy. To overcome these unwanted offset voltages use the offset-compensated ohms measurement method. In general, this method measures resistance (V/I) at a specific I-Source level and then subtracts a resistance measurement made with the I-Source set to a different level (typically zero).

NOTE *Offset Compensated Ω is also available from the CONFIG OHMS menu structure. Using Offset Compensated Ω from this menu automatically selects zero as one of the source values. For details, see "Offset compensated ohms" in "Basic ohms measurement procedures."*

This two-point measurement method is mathematically expressed as:
Offset Compensated $\Omega = \Delta V / \Delta I$ where $\Delta V = V2 - V1$ and $\Delta I = I2 - I1$.

- V1 is the voltage measurement with the I-Source set to a specific level.
- V2 is the voltage measurement with the I-Source set to a different level (typically zero).
- I1 is the current measurement with the I-Source set to a specific level.
- I2 is the current measurement with the I-Source set to a different level (typically zero).

You will be prompted to enter the two I-Source values (see "Selecting and enabling math expression").

Varistor alpha

This math formula is used to determine ALPHA (α), which is the logarithmic ratio of two voltage measurement points on a non-linear V-I curve and is expressed as follows:

$$\text{ALPHA} = \frac{\log (I2/I1)}{\log (V2/V1)}$$

where: V1 is the voltage measurement at the first I-Source point.
V2 is the voltage measurement at the second I-Source point.
The log (x) function uses the absolute value of x.

When configuring this math function (see "Selecting and enabling math expression"), you will be prompted to enter the two I-source values.

Voltage coefficient

High value or high-megohm resistors exhibit a change in resistance with a change in applied voltage. This effect is known as voltage coefficient. The voltage coefficient is the percent change in resistance per unit change in applied voltage and is defined as follows:

$$\text{Voltage Coefficient (\%)} = \frac{\Delta R}{R2 \times \Delta V} \times 100\%$$

where: $\Delta R = R2 - R1$
$\Delta V = V2 - V1$

R1 is the resistance measurement at the first source point.
R2 is the resistance measurement at the second source point.
V1 is the voltage measurement at the first source point.
V2 is the voltage measurement at the second source point.

If sourcing voltage, you will be prompted to enter the two V-source values. If sourcing current, you will be prompted to enter the two I-source values (see "Selecting and enabling math expression").

Percent Deviation

The following math calculation provides the percent deviation between the normal display reading and the user specified reference value:

$$\text{\% Deviation} = \frac{(X - Y)}{Y} \times 100$$

where: X is the normal display measurement reading.
Y is the reference value.

The reference value (Y) can be a user-specified value or a reading acquired by the SourceMeter. See "Selecting and enabling math expression" to set the reference value.

NOTE *The reading format is fixed at ±XXX.XXX%.*
This math expression is not available for remote operation.

Selecting and enabling math expression

Perform the following steps to select and enable a math expression:

1. Select the appropriate source (V or I) for the math expression.
2. Press CONFIG and then FCTN to display the math expression selections. Place the cursor on the desired math expression and press ENTER:
   - For 2-point math expressions, you will be prompted to enter the two source values. Press ENTER after entering each source value.
   - For Percent Deviation, you will be prompted to set the reference value. The following methods are available:
     - User-specified reference value — Enter the desired reference value and press ENTER.
     - Acquire reference value — Press the AUTO range key. The SourceMeter will perform a measurement and display that reading as the reference. Press ENTER to select that reference value.
3. Turn on the output by pressing the ON/OFF key.
4. Press the FCTN key to enable the selected math function. The MATH annunciator will turn on, and the result of the math expression will be displayed.

Note that with FCTN enabled, the sweep for a 2-point math expression runs continuously. Each sweep updates the reading. The source value cannot be changed while the 2-point sweep is running. However, the range keys remain active.

3
Source-Measure Options

Introduction

This section includes the following information:

- Measurement configuration:
  — range, filter, relative, digits, and speed
- Source configuration:
  — remote sense, guard, delay, and protection
- Trigger operations
  — trigger model, trigger link, and configure triggering
- Data store
- Digital I/O port
- Configure operate
  — interlock, output off state, and auto operate off
- Main menu
  — default setups, communications, cal, front panel tests, digital output states, auto zero, timestamp, numeric display format, and beeper

Measurement configuration

The following paragraphs discuss configuring the SourceMeter for making measurements. See the end of Appendix A for information about optimizing readings for speed or accuracy.

Range

The selected measurement range affects the accuracy of the measurements as well as the maximum signal that can be measured. Note that with the output off, dashed lines are displayed (i.e., --.---- μA), to indicate that measurements are not being performed.

Maximum readings

The full scale input for each voltage, current, and auto ohms measurement range is defined by the selected range. For example, ±2.2V is the full scale reading for the 2V range, ±110mA is the full scale reading for the 100mA range, and ±2.2kΩ is the full scale reading for the 2kΩ range.

For manual ohms measurements, the display reading is the result of the V/I calculation. Effectively, there are no ohms ranges. Thus, there are never any leading zeroes in the display reading. For example, a resistor that is measured at 936.236kΩ will be displayed as 936.236kΩ (5½ digit resolution). The RANGE keys are used to select the voltage or current measurement range.

Input levels that exceed the maximum levels cause the "OVERFLOW" message to be displayed.

Ranging limitations

- When sourcing voltage (Source V), you cannot use the RANGE keys to change the voltage measurement (Measure V) range. Also, when sourcing current (Source I), you cannot use the RANGE keys to change the current measurement (Measure I) range. For these source-measure configurations, the measurement range is determined by the selected source range.
- With the 60V V-Source range selected, the highest current measurement range is 1A. With the 1A I-Source range selected, the highest voltage measurement range is 60V. With the 3A I-Source range selected, the highest voltage measurement range is 20V.
- The present I-Compliance range determines the highest current measurement range that can be selected. Similarly, the present V-Compliance range determines the highest voltage measurement range that can be selected. For example, if I-Compliance is on the 100mA range, the highest current measurement range that can be selected is 100mA. If V-Compliance is on the 2V range, the highest voltage measurement range that can be selected is 2V.

Manual ranging

For the Source V Measure I, Source I Measure V, and Ohms configurations, the RANGE ▲ and ▼ keys are used to select a fixed range. Note that the highest available range is dependent on the corresponding compliance setting (see "Ranging limitations").

If the instrument is in range compliance or displays the "OVERFLOW" message, select a higher range until an on-range reading is displayed. Use the lowest range possible without causing an overflow to ensure best accuracy and resolution.

Autoranging

For the Source V Measure I, Source I Measure V, and Ohms configurations, press AUTO RANGE to enable autoranging. The AUTO annunciator turns on when autoranging is selected. With autoranging selected, the instrument automatically chooses the best range to measure the applied signal. Note that the highest available range is dependent on the corresponding compliance setting (see "Ranging limitations").

Filter

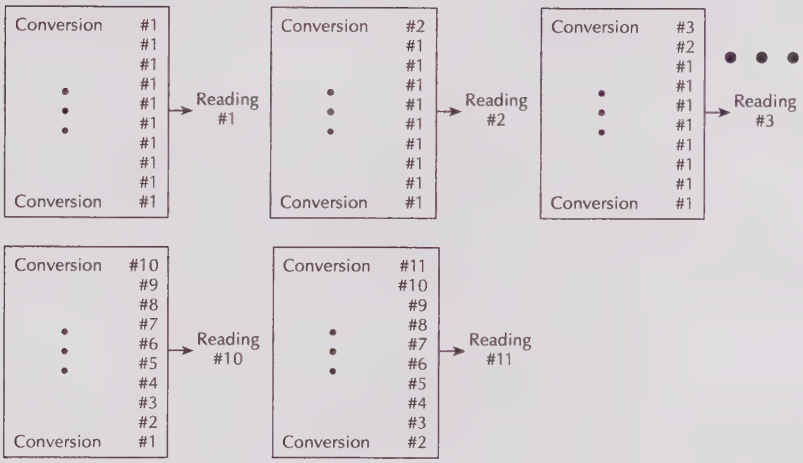
Filter lets you set the filter response to stabilize noisy measurements. The Model 2420 uses a digital filter, which is based on reading conversions. The displayed, stored, or transmitted reading is an average of a number of reading conversions (from 1 to 100).

There are two averaging filter types to choose from: repeating and moving (see Figure 3-1). For the repeating filter (which is the power-on default), the stack (filter count) is filled, and the conversions are averaged to yield a reading. The stack is then cleared, and the process starts over. Choose this filter for sweeping so readings for other source levels are not averaged with the present source level.

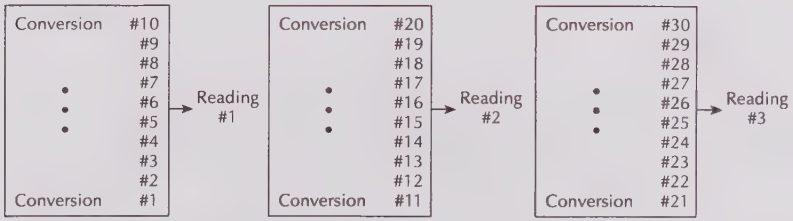
The moving average filter uses a first-in, first-out stack. When the stack (filter count) becomes full, the measurement conversions are averaged, yielding a reading. For each subsequent conversion placed into the stack, the oldest conversion is discarded. The stack is re-averaged, yielding a new reading.

When the filter is first enabled, the stack is empty. Keep in mind that a filtered reading is not yielded until the stack is full. The first reading conversion is placed in the stack and is then copied to the other stack locations in order to fill it. Thus, the first filtered reading is the same as the first reading conversion. Now the normal moving average filter process can continue. Note that a true average is not yielded until the stack is filled with new reading conversions (no copies in stack). For example, in Figure 3-1A, it takes ten filtered readings to fill the stack with new reading conversions. The first nine filtered readings are calculated using copied reading conversions.

Figure 3-1
Moving average and repeating filters



A. Type - Moving Average, Readings = 10



B. Type - Repeating, Readings = 10

Configuring Filter

Filter type and count is configured from the CONFIGURE FILTERING menu and is structured as follows. Use the "Rules to navigate menus" in Section 2 to check and/or change the filter configuration.

CONFIGURE FILTERING menu

Press CONFIG and then FILTER to display the menu.

- AVERAGING TYPE — Use this menu item to select filter type (MOVING or REPEAT).
- AVERAGE COUNT — Use this menu item to specify filter count (1 to 100 readings).

NOTE *The configured filter is the same for all measurement functions.*

Enabling Filter

The filter is enabled by pressing the FILTER key. The "Filter Enabled" message and the filter count are briefly displayed. The FILT annunciator is on while the filter is enabled. Pressing FILTER a second time disables filter.

Response time

The filter parameters have speed and accuracy tradeoffs for the time needed to display, store, or output a filtered reading. These affect the number of reading conversions for speed versus accuracy and response to input signal changes.

Relative

The rel (relative) feature can be used to null offsets or subtract a baseline reading from present and future readings. With REL enabled, subsequent readings will be the difference between the actual input value and the rel value as follows:

Displayed Reading = Actual Input - Rel Value

Once a rel value is established for a measurement function, the value is the same for all ranges. For example, if 50V is set as a rel value on the 60V range, the rel is also 50V on the 20V, 2V, and 200mV ranges.

Selecting a range that cannot accommodate the rel value does not cause an overflow condition, but it also does not increase the maximum allowable input for that range. For example, on the 20V range, the SourceMeter still overflows for a >22V input.

NOTE *When rel is enabled, the REL annunciator turns on. Changing measurement functions disables rel.*

Zero correction

Rel can be used to null out zero offsets or to establish a zero baseline by pressing the REL key. The reading (which becomes the rel value) is subtracted from itself. As a result, a zero reading is displayed. Pressing REL a second time disables rel.

Defining a rel value

A unique rel value can be established for the selected measurement function as follows:

1. Press CONFIG and then REL. The present rel value will be displayed.
2. Set the desired rel value (see "Rules to navigate menus" in Section 2 for details).
3. With the desired rel value displayed, press ENTER. The SourceMeter will return to the normal source-measure display with rel enabled. The reading will reflect the defined rel value.

Digits

The display resolution of the measure reading depends on the DIGITS setting. This setting is global, which means the digits setting selects display resolution for all measurement functions.

The DIGITS setting has no effect on the remote reading format. The number of displayed digits does not affect accuracy or speed. Those parameters are controlled by the SPEED setting.

Setting display resolution

There are two ways to set display resolution:

- **DIGITS** — Press the DIGITS key until the desired number of digits is displayed.
- **CONFIG DIGITS** — Press CONFIG and then DIGITS to display the digits menu. Place the cursor on the desired number of digits (3.5, 4.5, 5.5, or 6.5) and press ENTER.

NOTE *The concurrent measurement (available on the secondary display by using the TOGGLE key) is always 5½ digits.*

Changing SPEED changes DIGITS, but changing DIGITS does not change SPEED.

Speed

The Speed/Accuracy menu is used to set the integration time of the A/D converter (period of time the input signal is measured). The integration time affects the usable digits, the amount of reading noise, and the ultimate reading rate of the instrument. The integration time is specified in parameters based on the number of power line cycles (NPLC), where 1 PLC for 60Hz is 16.67msec (1/60) and 1 PLC for 50Hz and 400Hz is 20msec (1/50).

In general, the fastest integration time (FAST; 0.01 PLC) results in increased reading noise and fewer usable digits. The slowest integration time (HI ACCURACY; 10 PLC) provides the best common-mode and normal-mode rejection. In-between settings are a compromise between speed and noise. The default power-on speed setting is NORMAL (1 PLC).

Setting speed

Speed is set from the SPEED ACCURACY MENU and is structured as follows. Use the "Rules to navigate menus" in Section 2 to check and/or change the speed setting.

SPEED-ACCURACY menu

Press SPEED or CONFIG SPEED to display the menu.

- **FAST** — Sets speed to 0.01 PLC and sets display resolution to 3½ digits.
- **MED** — Sets speed to 0.10 PLC and sets display resolution to 4½ digits.
- **NORMAL** — Sets speed to 1.00 PLC and sets display resolution to 5½ digits.
- **HI ACCURACY** — Sets speed to 10.00 PLC and sets display resolution to 6½ digits.
- **OTHER** — Use to set speed to any PLC value from 0.01 to 10. Display resolution is not changed when speed is set with this option.

NOTE *After setting speed, display resolution can be changed using the DIGITS key.*

Source configuration

Menus are used to configure the following aspects of V-Source and I-Source operation:

- Enable or disable remote sensing.
- Select guard mode (cable or ohms).
- Set additional settling time for the sources.
- Set voltage protection limit for the V-Source.

Configure V-source and I-source

The V-Source is configured from the CONFIGURE V-SOURCE menu and the I-Source is configured from the CONFIGURE I-SOURCE menu. Guard, source delay, and auto source delay can be set from either of the two source menus. The voltage protection limit and sense mode are set from the CONFIGURE V-SOURCE menu. Use the "Rules to navigate menus" (in Section 2) to check and/or change source options.

CONFIGURE V-SOURCE and CONFIGURE I-SOURCE menus

Press CONFIG and then SOURCE V or I to display the desired configuration menu.

- **PROTECTION (V-source only)** — Use this option to select the maximum voltage level the SourceMeter can output. Available limit values include 6V, 12V, 18V, 24V, 30V, 36V, 48V, and NONE. These are absolute values with 5% tolerance. The power-on default is 36V.

WARNING **Even with the voltage protection limit set to the lowest value (6V), NEVER touch anything connected to the terminals of the SourceMeter when the OUTPUT is ON. Always assume that a hazardous voltage (>30V rms) is present when the OUTPUT is ON.**

To prevent damage to DUT (devices under test) or external circuitry, DO NOT program the V-Source to levels that exceed the voltage protection limit.

- **SENSE MODE (V-source only)** — Use this option to select two-wire (local) sensing (default) or four-wire (remote) sensing.
- **GUARD** — Use this option to select OHMS guard or CABLE guard. Ohms guard is used for in-circuit ohms measurements, and cable guard is used to provide a driven guard for high-impedance test circuits (see "Basic circuit configurations" in Section 2).
- **DELAY** and **AUTO DELAY**— These options are used to set the settling time for the source. This source delay is the delay phase of the Source-Delay-Measure (SDM) cycle. The AUTO DELAY option is used to automatically set the delay. The delay period depends on which source range is presently selected. When on the 3A I-Source range, enabling auto delay sets the delay to 2msec. When on any other source range (V or I), enabling auto delay sets the delay to 1msec. The DELAY option is used to manually set the delay from 000.0000 seconds to 999.9999 seconds. Manually setting the delay disables AUTO DELAY.

Trigger operations

The following paragraphs discuss front panel triggering (trigger model) and external triggering using the Trigger Link.

NOTE *All aspects of triggering, including programming the trigger model and selecting Trigger Link input/output lines, are configured from the CONFIGURE TRIGGER menu (see "Configure triggering").*

Trigger model

The flowchart in Figure 3-2 summarizes triggering for front panel operation. The trigger is modeled after the SCPI commands used to control triggering. Two layers of operation (arm layer and trigger layer) are used to provide versatility.

Unless otherwise noted, the programmable aspects of the trigger model are performed from the CONFIGURE TRIGGER menu (see "Configure triggering").

Idle

The SourceMeter is in idle when it is not operating in the arm layer or trigger layer of the trigger model. When in idle, the ARM annunciator is off. To take the SourceMeter out of idle, turn ON the OUTPUT.

The SourceMeter can be returned to the idle state at any time by selecting the HALT menu item of the CONFIGURE TRIGGER menu. Note that the output will not turn off when HALT is finished. Any reconfiguration of the SourceMeter will re-arm the trigger model.

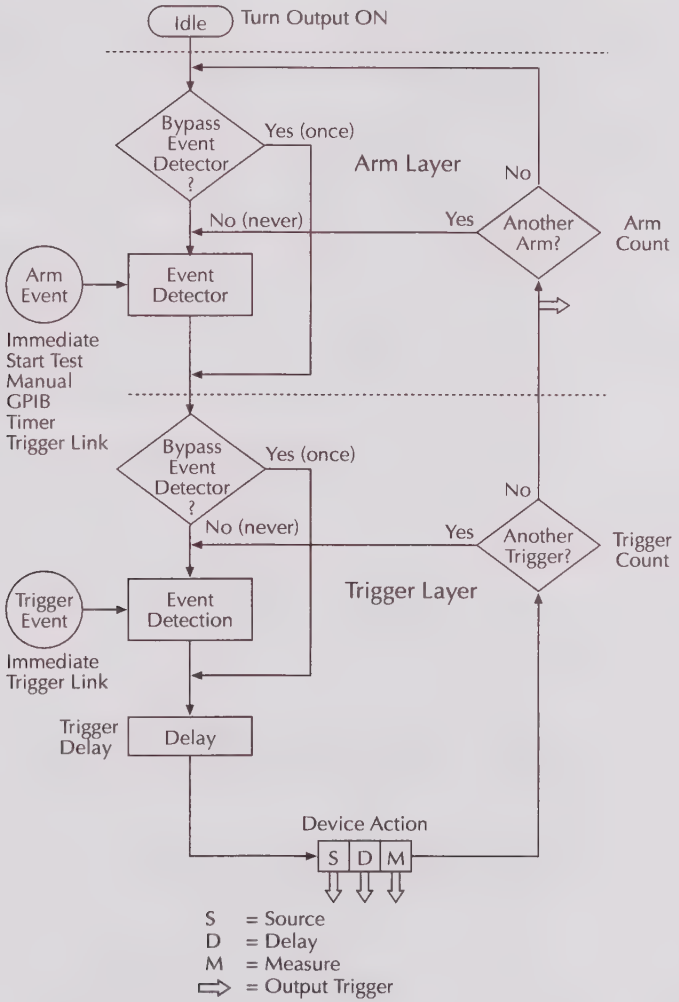


Figure 3-2
Trigger model (front panel operation)

Event detection

In general, operation is held up at an Event Detection block until the programmed event occurs. However, if event detection bypass is selected (ONCE), operation will loop around the Event Detection block.

The programmable events are described as follows:

- **Immediate** — Arm and trigger event detection occurs immediately allowing operation to continue.
- **Start Test** — Arm event detection occurs when the SOT pulse from a handler is received via the Digital I/O port (see "Limit testing" in Section 2).
- **Manual** — Arm event detection occurs when the TRIG key is pressed.
- **GPIB** — Arm event detection occurs when a bus trigger (GET or *TRG) is received.
- **Timer** — On the initial pass through the trigger model, arm event detection occurs immediately. On subsequent passes, event detection occurs when the programmed timer interval elapses.
- **Trigger Link** — Arm and trigger event detection occurs when an input trigger via the TRIGGER LINK input line is received. See "Trigger link" for more information.

Delay

A programmable delay is available after the trigger event occurs. After this delay elapses, operation proceeds to the device action.

Device action

The device action is made up of the Source-Delay-Measure (SDM) cycle and any output triggers that are enabled. After the source level is output, a delay period is used to allow the source to settle. The measurement is then performed (see "Source configuration" to set the source delay).

Note that if the repeat filter is being used, the specified number (filter count) of measurements will be performed to yield a single reading.

Counters

Programmable counters are used to repeat operations within the trigger model layers. For example, if performing a 10-point sweep, the trigger counter would be set to 10.

Operation will stay in the trigger layer until the 10 source-measure points of the sweep are performed. If you wanted to repeat the sweep three times, the arm counter would be set to three. Three 10-point sweeps can then be performed for a total of 30 source-measure actions.

The maximum buffer size for the SourceMeter is 2500 readings. Thus, the product of the two counters cannot exceed 2500. For example, if you set an arm count of two, the maximum trigger count will be 1250 (2500/2).

NOTE *When a sweep is configured, the trigger model settings will not change until the sweep is started. After the sweep is finished, the trigger model will reset back to the previous settings.*

Output triggers

The SourceMeter can be programmed to output a trigger (via rear panel Trigger Link connector) after various trigger model actions. An output trigger is used to trigger another instrument to perform an operation. See "Trigger link" for more information.

Trigger Layer Output Triggers — A trigger can be programmed to occur after any phase of the SDM cycle (device action). For example, when used with a scanner, the SourceMeter can output a trigger after each measurement to signal the scanner to select the next channel in the scan.

Arm Layer Output Trigger — The SourceMeter can also output a trigger after operation leaves the trigger layer and enters back into the arm layer.

Bench defaults

The bench defaults for the trigger model are:

- Arm Event = Immediate
- Trigger Event = Immediate
- Arm Count = 1
- Trigger Count = 1
- Delay = 0 sec
- Programmable Source Delay = 1msec
- Source Auto-Delay = Enabled
- Output Triggers = All output trigger are disabled (off).
- Event Detection Bypass = Never (both layers)

When the OUTPUT is turned ON, the SourceMeter will run in a continuous loop around the trigger model. After each measurement, an output trigger will be sent (via line #2 of the Trigger Link), and operation will return to the top of the trigger model where it will immediately drop down for the next device action. The SourceMeter can be returned to idle by turning the OUTPUT OFF.

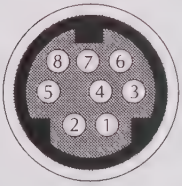
Trigger link

Input and output triggers are received and sent via the rear panel TRIGGER LINK connector. The trigger link has four lines. At the factory, line #2 is selected for output triggers, and line #1 is selected for input triggers. These input/output line assignments can be changed from the CONFIGURE TRIGGER menu (see "Configure triggering"). The connector pinout is shown in Figure 3-3.

Input trigger requirements

An input trigger is used to satisfy event detection for a trigger model layer that is configured for the TRIGGER LINK event (see "Trigger model"). The input requires a falling-edge, TTL compatible pulse with the specifications shown in Figure 3-4.

Rear Panel Pinout



Pin Number	Description
1	Trigger Link 1
2	Trigger Link 2
3	Trigger Link 3
4	Trigger Link 4
5	Trigger Link 5 (not used by 2420)
6	Trigger Link 6 (not used by 2420)
7	Ground
8	Ground

Figure 3-3
Rear panel pinout

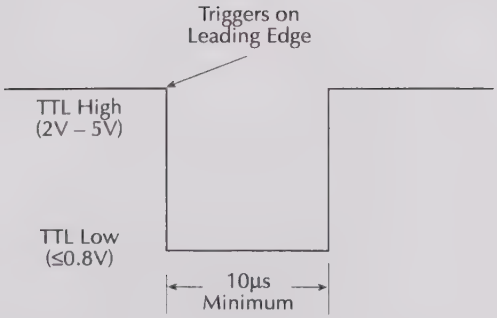
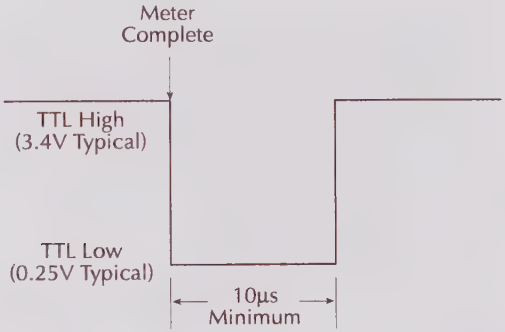


Figure 3-4
Trigger link input pulse specifications

Output trigger specifications

The SourceMeter can be programmed to output a trigger after various trigger model actions (see "Trigger model"). The output trigger provides a TTL-compatible output pulse that can be used to trigger other instruments. The specifications for this trigger pulse are shown in Figure 3-5. A trigger link line can source 1mA and sink up to 50mA.

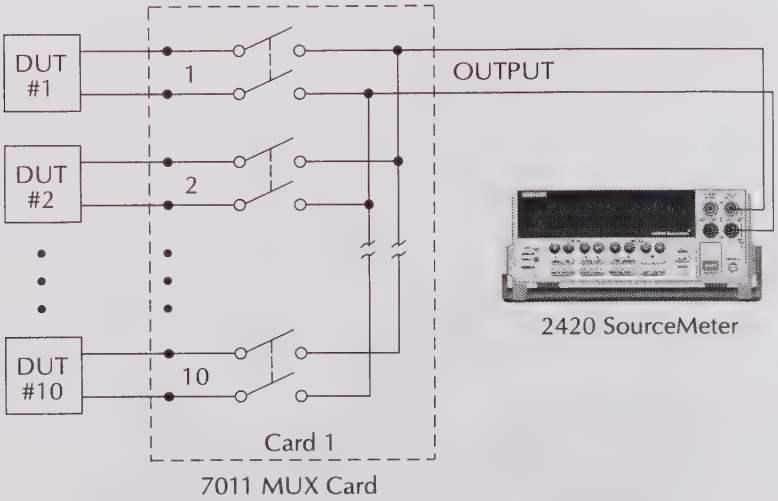
Figure 3-5
Trigger link output pulse specifications



External triggering example

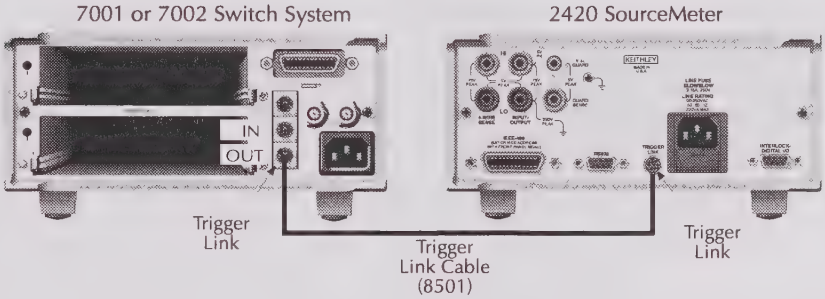
In a simple test system, you may want to close a switching channel and then measure the resistance of the DUT connected to that channel. Such a test system is shown in Figure 3-6, which uses a SourceMeter to measure 10 DUTs switched by a Model 7011 multiplexer card in a Model 7001/7002 Switch System.

Figure 3-6
DUT test system



The Trigger Link connections for this test system are shown in Figure 3-7. Trigger Link of the SourceMeter is connected to Trigger Link (IN or OUT) of the switching mainframe. Note that with the default trigger settings of the switching mainframe, line #1 is an input, and line #2 is an output.

Figure 3-7
Trigger link connections



For this example, the SourceMeter and Switching Mainframe are configured as follows:

SourceMeter

Bench defaults restored
Trigger-In Event = TLINk
Trigger Input Line = #2
Trigger Output Line = #1
Trigger Out Events: MEAS=ON(all others OFF)
Trig-Count = 10

Switching mainframe

Factory defaults restored
Scan list = 1!1-1!10,
Number of scans = 1
Channel Spacing = TrigLink

To store the readings in the SourceMeter buffer, press STORE and set the buffer size for 10. When ENTER is pressed, the asterisk (*) annunciator will turn on to indicate the buffer is enabled (see "Data store" for details).

Turn the SourceMeter OUTPUT ON. The SourceMeter waits for an external trigger from the switching mainframe.

Press STEP on the Model 7001/7002 to take it out of idle and start the scan. The scanner's output pulse triggers the SourceMeter to take a reading and store it. The SourceMeter then sends a trigger pulse to the switching mainframe to close the next channel. This process continues until all 10 channels are scanned, measured, and stored.

Details of this testing process are explained in the following paragraphs and are referenced to the operation model shown in Figure 3-8.

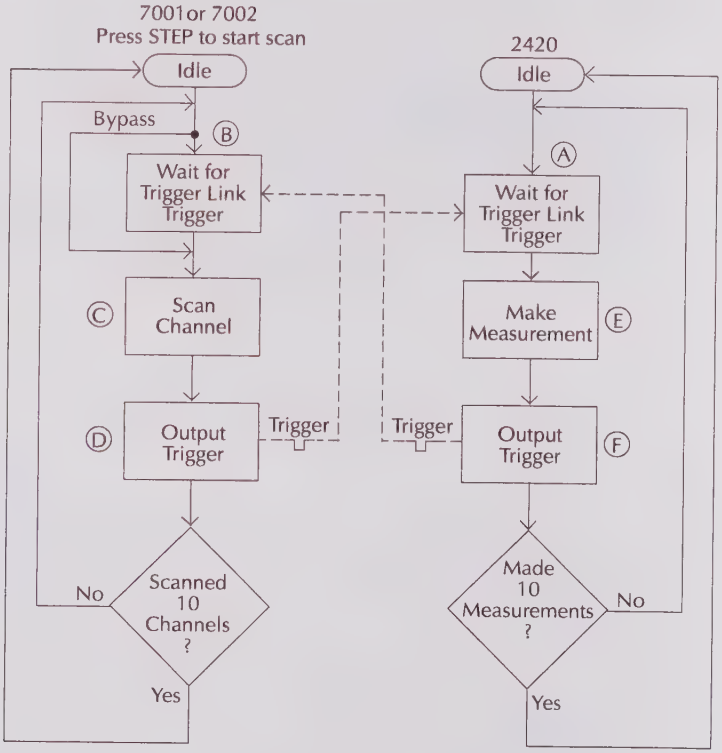


Figure 3-8
Operation model for triggering example

A) Turning the SourceMeter OUTPUT ON places it at point A in the flowchart, where it waits for an external trigger.

B) Pressing STEP takes the Model 7001/2 out of the idle state and places operation at point B in the flowchart.

C) For the first pass through the model, the scanner does not wait at point B. Instead, it closes the first channel (point C).

D) After the relay settles, the Model 7001/2 outputs a trigger pulse. Since the instrument is programmed to scan 10 channels, operation loops back to point B, where it waits for an input trigger.

E) and F) With the SourceMeter operation at point A, the output trigger pulse from the Model 7001/2 triggers a measurement of DUT #1 (point E). After the measurement is complete, the SourceMeter outputs a trigger pulse and then loops back to point A, where it waits for another input trigger.

The trigger applied to the Model 7001/2 from the SourceMeter closes the next channel in the scan, which then triggers the SourceMeter to measure that DUT. This process continues until all 10 channels are scanned and measured.

Configure triggering

Triggering is configured from the CONFIGURE TRIGGER menu and is structured as follows. Note that bullets indicate the primary items of the menu, while arrows and stars indicate options. Use the "Rules to navigate menus" in Section 2 to check and/or change trigger options.

NOTE *See "Trigger model" for details on the following programmable aspects of triggering.*

CONFIGURE TRIGGER menu

Press CONFIG and then TRIG to display menu.

- **ARM LAYER** — Use this menu item to configure the arm layer of the trigger model:
  - **ARM IN** — Use to select the detection event for the arm layer:
    - / IMMEDIATE — Event detection occurs immediately.
    - / START TEST — Event detection occurs when the SOT pulse from the component handler is received.
    - / MANUAL — Event detection occurs when the TRIG key is pressed.
    - / GPIB — Event detection occurs when a bus trigger (GET or *TRG) is received.
    - / TIMER — Initially, event detection is satisfied immediately. Subsequent event detection occurs after the timer interval elapses.After selecting this arm event, you will be prompted to specify the timer interval (in seconds).
    - / TRIGGER LINK — After selecting this arm event, you will be prompted to select the input line for the Trigger Link and the state of the event detection bypass. With ONCE selected, operation will loop around the arm event detector on each pass through the trigger model. With NEVER selected, operation always waits for the input trigger.
  - **ARM OUT** — Use to configure the arm layer output trigger:
    - / LINE — Select the Trigger Link line for the output trigger: line #1, #2, #3, or #4.
    - / EVENTS — Enable (ON) or disable (OFF) the arm layer output trigger.
  - **COUNT** — Specify the arm count.
- **TRIG LAYER** — Use this menu item to configure the trigger layer of the trigger model:
  - **TRIGGER IN** — Use to select the detection event for the trigger layer:
    - / IMMEDIATE — Event detection occurs immediately.
    - / TRIGGER LINK — After selecting this trigger event, you will be prompted to select the input line for the Trigger Link and the state of the event detection bypass. With ONCE selected, operation will loop around the trigger event detector and the delay on each new pass through the trigger model. With NEVER selected, operation always waits for the input trigger.
  - **TRIGGER OUT** — Use to configure the trigger layer output trigger:
    - / LINE — Select the Trigger Link line for the output trigger; line #1, #2, #3, or #4.
    - / EVENTS — Enable (ON) or disable (OFF) output triggers that occur after the source, delay, and measure actions.
  - **DELAY** — Specify the time delay (in seconds) for the trigger delay.
  - **COUNT** — Specify the trigger count.
- **HALT** — Use to return the SourceMeter to the idle state. HALT does not turn off the output. The programmed source level will still be available at the OUTPUT terminals. The following actions will take the SourceMeter out of idle:
  - Turn the output off and then on again.
  - Re-select the arm or trigger event.
  - Exit from the menu structure, and then re-enter it by pressing CONFIG and then TRIG.

Data store

The SourceMeter has a data store (buffer) to store from 1 to 2500 source-measure readings. The instrument stores the source-measure readings that are displayed during the storage process. Each source-measure reading also includes the buffer location number and a timestamp. The compliance reading (Cmpl) is not stored.

The data store also provides statistical data on the measured readings stored in the buffer. These include minimum, maximum, mean, and standard deviation.

Storing readings

Perform the following steps to store readings:

1. Set up the SourceMeter for the desired configuration.
2. Press the STORE key.
3. Use the cursor keys, and the SOURCE (▲ and ▼) or RANGE (▲ and ▼) keys to specify the number of readings to store in the buffer.
4. Press ENTER. The asterisk (*) annunciator turns on to indicate data storage operation. It will turn off when the storage is finished.

Recalling readings

Readings stored in the buffer are displayed by pressing the RECALL key. The source-measure readings are positioned at the left side of the display, while the buffer location number and timestamp are positioned at the right side.

The buffer location number indicates the memory location of the source-measure reading. Location #0000 indicates that the displayed source-measure reading is stored at the first memory location. The timestamp references readings to zero seconds. Thus, the first source-measure reading (#0000) is timestamped at 0000000.000 seconds.

To display the other source-readings stored in the buffer, display the desired memory location number. The ▲ and ▼ keys for SOURCE and RANGE increment and decrement the selected digit of the location number. Cursor position is controlled by the ◄ and ► keys. When scrolling forward past the last stored reading, the buffer wraps to the first stored reading. Conversely, when scrolling in reverse past the first stored reading, the buffer wraps to the last stored reading. A different key click tone announces the wrap-around.

The memory location number can also be keyed in using the 0 through 9 number keys. Position the cursor on the appropriate digit and press the desired number key. The cursor then moves right to the next least significant digit. For example, to display reading #0236, position the cursor all the way to the left (MSD) and press 0, 2, 3, 6. Note that if keying in a number that exceeds the buffer size, the reading at the highest memory location is displayed.

To exit from the data store recall mode, press EXIT.

Buffer Statistics — With the data store in recall, buffer statistics are displayed by using the TOGGLE key. Use the TOGGLE key to sequence through the statistics and return the SourceMeter to the normal data store recall state. Pressing EXIT at any time returns the instrument to the normal source-measure display state.

- **Minimum and Maximum** — Displays the minimum and maximum readings stored in the buffer. The buffer location number is also provided for these readings. If desired, you can go to those buffer locations to obtain more data about the readings.
- **Average** — Displays the mean (average) of all measured readings stored in the buffer. The following equation is used to calculate mean:

$$y = \frac{\sum_{i=1}^{n} X_i}{n}$$

where: X_i is a stored reading.
n is the number of stored readings.

- **Standard Deviation** — Displays the standard deviation of buffered readings. The following equation is used to calculate standard deviation:

$$y = \sqrt{\frac{\sum_{i=n-1}^{n} X_i^2 - \left(\frac{1}{n}\left(\sum_{i=1}^{n} X_i\right)^2\right)}{n-1}}$$

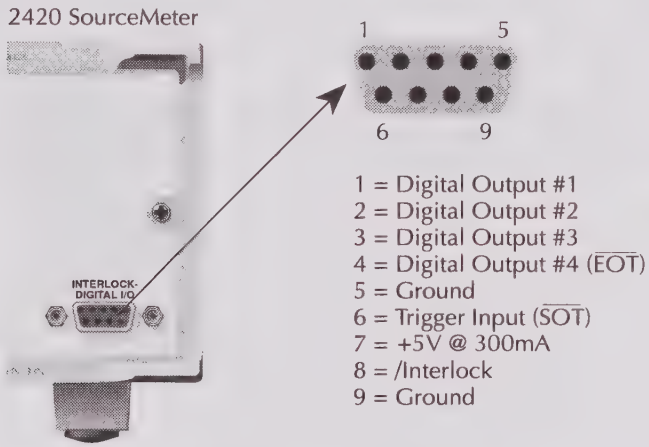
where: X_i is a stored reading.
n is the number of stored readings.

- **Peak-to-Peak** — Displays the peak-to-peak reading (peak-to-peak = Maximum - Minimum).

Digital I/O port and safety interlock

The SourceMeter has a digital input/output port that can be used to control external digital circuitry, such as a handler that is used to perform binning operations when testing limits. The digital I/O port is located on the rear panel and is shown in Figure 3-9.

Figure 3-9
Interlock and digital I/O port



The port provides four output lines and one input line. Each open-collector output can be set high (+5V) or low (0V). Each output line can source up to 2mA or sink up to 500mA. When using a category register handler for limit testing, output line #4 is typically used for the EOT (end-of-test) pulse. This pulse from the SourceMeter signals the handler to perform the binning operation.

The input line (/SOT) is used by a handler to start limit testing. With the START TEST arm event selected, the handler must pulse /SOT low in order to provide event detection, which starts the testing process.

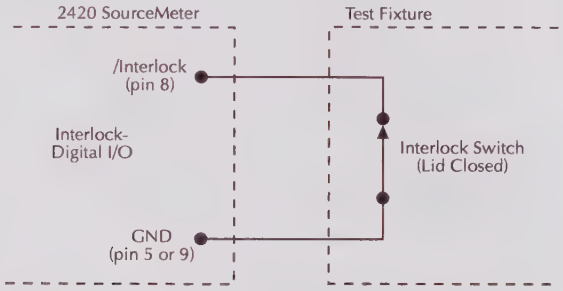
NOTE *See "Limit testing" in Section 2 for details on performing limit tests and "Trigger operations" for information on programming the SourceMeter to respond to the low-going SOT (start-of-test) pulse from a handler.*

Interlock — Also provided by the digital I/O port is an interlock line for use with a test fixture interlock switch. When properly used, the OUTPUT of the SourceMeter will turn OFF when the lid of the test fixture is opened. See "Connections" in Section 2 for important safety information when using the test fixture interlock.

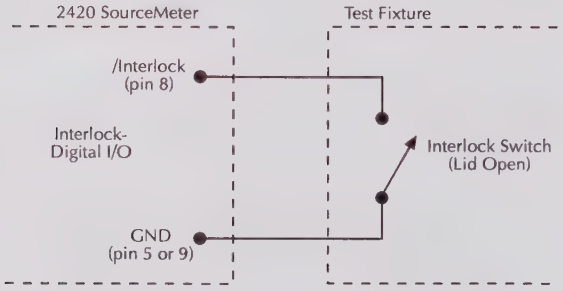
When the interlock is enabled (see "Configure operate"), the output of the SourceMeter cannot be turned on unless the interlock line is pulled low through a switch to ground as shown in Figure 3-10A. If the lid of the test fixture opens (Figure 3-10B), the switch opens, and the interlock line goes high turning the OUTPUT of the SourceMeter OFF. The output can only be turned back on by first closing the lid of the test fixture and then pressing the OUTPUT ON/OFF key.

+5V — The digital I/O port provides a +5V output that can be used to drive external logic circuitry. Maximum current output for this line is 300mA. This line is protected by a self-resetting fuse (one hour recovery time).

Figure 3-10
Using test fixture interlock



A) SourceMeter OUTPUT can be turned on.



B) SourceMeter OUTPUT turns off.

Configure output

The output is configured from the CONFIGURE OUTPUT menu and is structured as follows. Note that bullets indicate the primary items of the sweep menu, while arrows indicate options. Use the "Rules to navigate menus" in Section 2 to check and/or change operate options.

Configure OUTPUT menu

Press CONFIG and then ON/OFF to display the menu.

- **INTERLOCK** — Use to ENABLE or DISABLE the interlock line of the Digital output. This line is used as an interlock for a test fixture (see "Digital I/O port").
- **OFF STATE** — Use to select the OFF state of the output (see "Output-off states" for details).
  - — **HIGH IMPEDANCE** — When the OUTPUT is turned OFF, the output relay opens. This disconnects external circuitry from the input/output of the SourceMeter.
  - — **NORMAL** — When the OUTPUT is turned off, the V-Source is selected and set to 0V. Current compliance is set to 0.5% full scale of the present current range.
  - — **ZERO** — When the V-Source OUTPUT is turned off, the V-Source is set to 0V and current compliance is not changed. When the I-Source OUTPUT is turned off, the V-Source mode is selected and set to 0V. Current compliance is set to the programmed Source I value or to 0.5% full scale of the present current range, whichever is greater. Measurements are performed and displayed while the OUTPUT is off.
  - — **GUARD** — When the OUTPUT is turned OFF, the current source is selected and set to 0A. Voltage compliance is set to 0.5% full scale of the present voltage range.
- **AUTO OFF** — Use to ENABLE or DISABLE auto output off. When enabled, the OUTPUT will turn off after the measurement phase of every SDM cycle. The OUTPUT turns back on at the beginning of the next SDM cycle. When disabled, the OUTPUT stays on as long as the SourceMeter is operating within the trigger model (ARM annunciator on). With the OUTPUT enabled, pressing the ON/OFF key will disable the OUTPUT and disable auto output off.

Output Off States

HIGH IMPEDANCE — With this output-off state, the output relay opens when the OUTPUT is turned OFF. This disconnects external circuitry from the input/output of the SourceMeter. To prevent excessive wear on the output relay, do not use this output off state for tests that turn the output off and on frequently (such as the Output Auto-Off mode). Note that there is a 15msec settling time for the relay when the output is turned on.

NORMAL — When in this relatively high-impedance output-off state, the V-Source is selected and set to 0V. Current compliance is set to 0.5% full scale of the present current range. In theory, with the V-Source set to zero, the SourceMeter will not source or sink power. In practice, the source value may not be exactly at zero. Therefore, the SourceMeter may source or sink a very small amount of power. In most cases, this source or sink power level is not significant.

ZERO — When in this output-off state, the "ZER" message is displayed (instead of "OFF"), and the SourceMeter is configured as follows:

When the V-Source is the selected source:

- The programmed V-Source value remains on the display.
- Internally, the V-Source is set to 0V.
- The current compliance setting remains the same as the output-on value. "Real" and "range" compliance detection remains active.
- Measurements are performed and displayed.

When the I-Source is the selected source:

- The programmed I-Source value remains on the display.
- Internally, the V-Source is selected and set to 0V.
- Current compliance is set to the programmed Source I value or to 0.5% full scale of the present current range, whichever is greater.
- Measurements are performed and displayed.

While in the ZERO output-off state, the SourceMeter can be used as an I-Meter.

The ZERO output-off state can also be used with the V-Source and Output Auto-Off to generate very quick pulsed voltage waveforms. For example, with Output Auto-Off enabled, you can generate 0 to +5V pulses. While in this relatively low-impedance output-off state, the Source-Meter will be able to quickly dissipate (sink) current caused by high input capacitance (i.e., cable capacitance) or an external source. This results in fast settling time. If you instead used the NORMAL output-off state for this application, current would dissipate very slowly (slow settling time) resulting in distorted pulses.

GUARD — With this output-off state, the current source is selected and set to 0A. Voltage compliance is set to 0.5% full scale of the present voltage range. This output-off state should be used when performing 6-wire guarded ohms measurements or for any other load that uses an active source.

NOTES *When changing the output-off state with the output off, the selected output-off state will be entered immediately.*

On power-up, the SourceMeter will momentarily be in the HIGH IMPEDANCE output-off state before going to the selected power-on output-off state.

If an Over-Temperature condition occurs, the SourceMeter will go into the HIGH IMPEDANCE output-off state.

Main menu

The Main Menu is used to select, configure, and/or perform various instrument operations. These include default setup conditions, communications (GPIB or RS-232), calibration, front panel tests, digital outputs states, auto zero, timestamp, numeric display format, and the beeper.

Options of the Main Menu are selected and configured from the MAIN MENU, which is structured as follows. Note that bullets indicate the primary items of the menu, while arrows and stars indicate options. Use the "Rules to navigate menus" (in Section 2) to check and/or change Main Menu options.

MAIN MENU

Press the MENU key to display the menu.

- **SAVESETUP —** Use to configure setup conditions:
  - **GLOBAL —** Use the following options to control instrument settings. Affected settings are listed in Appendix E:
    - / SAVE — Saves the present SourceMeter setup to a memory location (0 to 4).
    - / RESTORE — Returns the SourceMeter to a setup saved in memory (0 to 4).
    - / POWERON — Use to select the power-on default setup:
      - BENCH or GPIB — Powers-on to the BENCH or GPIB default conditions (see Appendix E).
      - USER SETUP NUMBER — Powers-on to a setup saved at a specified memory location (see SAVE).
    - / RESET — Returns the SourceMeter to BENCH or GPIB defaults (see Appendix E).
  - **SOURCE MEMORY —** Use the following options to control source setup configurations used for a Memory Sweep:
    - / SAVE — Use this option to save the present SourceMeter setup configuration to a memory location (1 to 100).
    - / RESTORE — Use this option to return the instrument to the SourceMeter setup configuration saved in a memory location (1 to 100).
- **COMMUNICATION** — Use to select and configure the remote operation interface:
  - **GPIB** — Use to select the GPIB (IEEE-488 Bus) and set the primary address (0 to 30). The factory default address is 24. Note that the address must not conflict with the address of the controller or any other instrument on the bus.
  - **RS-232** — Use to select the RS-232 interface, and set the following parameters:
    - / BAUD — Select the baud rate: 19200, 9600, 4800, 2400, 1200, 600, or 300.
    - / BITS — Select the number of data bits: 7 or 8.
    - / PARITY — Select parity: NONE, ODD, or EVEN.
    - / TERMINATOR — Select terminator: CR, CR+LF, LF, or LF+CR.
    - / FLOW CTRL — Select flow control: NONE or XON/XOFF.

NOTE *When the remote operation interface selection (GPIB or RS-232) is changed, the SourceMeter performs a power-on reset. To check or change options of the selected interface, you will have to re-enter the menu structure.*

- **CAL** — This menu item is used to calibrate the SourceMeter. Calibration is to be performed by qualified service personnel using the calibration procedure provided in the Model 2420 Service Manual. The only user accessible menu option is described as follows:
  - **VIEW DATES** — With this option selected, the next calibration date is displayed. This is one year from the last calibration, which is also displayed. The displayed count indicates how many times the SourceMeter has been calibrated.
- **TEST** — Use this menu item to perform tests on the SourceMeter:
  - **FRONT PANEL TESTS** — Use this menu option to test front panel keys and display digits:
    - / KEYS — Front panel keys are tested. Pressing a key displays a message that identifies that key. Pressing EXIT twice cancels the test.
    - / DISPLAY PATTERNS — When this test is selected, all display pixels and annunciators are turned on. The next press of a front panel key turns off the annunciators and corner pixels of each digit. The next press of a front panel key tests the rows of the top-left display digit. The next press of a front panel key tests all annunciators and pixels of each digit in a sequential manner. Press EXIT to cancel the test.
    - / CHAR SET — When this test is selected, the special display characters are displayed. Press EXIT to cancel the test.
- **GENERAL** — Use this menu item for the following general operations:
  - **DIGOUT** — Use to set the output lines of the Digital I/O port HI (+5V) or LOW (0V). See "Limit testing" in Section 2 and "Digital I/O port" for details.
  - **SERIAL#** — Displays the serial number of the SourceMeter, the firmware revision level for the main microcontroller (along with the date and time of the revision), the SCPI version, and the firmware revision level of the display (VFD) microcontroller.
  - **A/D CONTROLS** — Use to control auto-zero and select line frequency:
    - / AUTO ZERO — Every A/D conversion (reading) is calculated from a series of zero, reference, and signal measurements. With auto zero enabled (ON), all three of these measurements are performed for each reading to achieve rated accuracy. With auto-zero disabled (OFF), zero and reference are not measured. This increases measurement speed, but zero drift will eventually corrupt accuracy. With auto zero disabled, periodically change SPEED.
    - / LINE FREQUENCY — Use to manually set the line frequency (50 or 60Hz) or select AUTO. To manually set line frequency to 400Hz, select 50Hz. With AUTO selected, the SourceMeter will sense the line frequency on power-up and set the frequency accordingly. The line frequency setting is displayed during the power-on sequence.
  - **TIMESTAMP** — Use to reset the timestamp:
    - / RESET TIME — Reset the timestamp to zero.
  - **NUMBERS** — Use to select the engineering units (ENGR) or scientific notation (SCIENTIFIC) display format.

- **BEEPER** —Use to enable (ON) or disable (OFF) the beeper. When enabled, a "beep" will sound each time a front panel key is pressed.
- **FAN** — Use to set fan speed for when the output is off:
  - / ALWAYS — Fan speed (output on or off) is current range (source or measure) dependent. On the 10µA, 100µA, and 1mA ranges, the fan runs at the low speed (50%). On the 10mA and 100mA ranges, the fan runs at the medium speed (75%). On the 1A and 3A ranges, the fan runs at the high speed (100%).
  - / OUTPUT ON — With this selection, the fan runs at the low speed (50%) when the output is turned off. When the output is turned on, fan speed is again range dependent.

4
Remote Operation

Introduction

This section includes the following information:

- Differences - remote vs. local operation
- Selecting an interface
- GPIB bus operation and reference
- Status structure
- Trigger model (GPIB operation)
- Programming syntax
- Common commands
- RS-232 operation

Differences: remote vs. local operation

Operation enhancements (remote operation)

There are some source-measure operations you can do over the IEEE-488 bus and RS-232 interface that you cannot do from the front panel and are summarized as follows:

Math Expressions — There are 5 math expressions available from the panel. All except the Percent Deviation are available as pre-defined math expressions for remote operation. However, remote operations allows you to create up to 5 user-defined math expressions for a total of 9 expressions. An example program shows how to create Percent Deviation as a user-defined math expression.

Concurrent Measurements — With the use of the TOGGLE key, you can measure (display) two functions concurrently. Using remote operation, you can perform concurrent measurements on all three functions (voltage, current and resistance). See SENSe Subsystem for details.

Local to remote transition

When changing from local to remote operation, the following actions occur:

- The SourceMeter stops performing source-measure operations and returns to the idle state (ARM annunciator off).
- All sweep operations are aborted.
- All menus are exited.
- All pending front panel commands are aborted.
- Source and compliance editing are disabled.
- Data in the sample buffer is lost (i.e., :FETCh?, :CALC1:DATA?, and :CALC2:DATA? will not return any data until readings are taken while in remote).
- Concurrent measurements are enabled.
- All other settings are not affected, including those for the :TRACe buffer (data store).

Remote to local transition

When changing from remote to local operation, the following actions occur.

- The SourceMeter stops performing source-measure operations and returns to the idle state (ARM annunciator off).
- All sweep operations are aborted.
- All user-defined display messages are canceled.
- The display is turned on (if it was previously turned off).
- Source autoranging is disabled.
- Concurrent measurements are enabled.
- If resistance was enabled, source readback is enabled.
- The display is set to the default toggle state.
- Readings are continuously taken (if OUTPUT is on).

Selecting an interface

The Model 2420 supports two built-in remote interfaces:

- GPIB bus
- RS-232 interface

You can use only one interface at a time. The factory interface selection is the GPIB bus. You can select the interface only from the front panel. The interface selection is stored in non-volatile memory; it does not change when power has been off or after a remote interface reset.

The GPIB bus is the IEEE-488 interface. You must select a unique address for the Model 2420. The address is displayed when the SourceMeter is turned on. At the factory, the address is set to 24.

The RS-232 interface is a serial interface. Programmable aspects of this interface include the following. Factory default settings are shown in parentheses.

Baud Rate (9600)
Data Bits (8)
Parity (none)
Terminator (CR)
Flow Control (none)

An interface is selected and configured from the COMMUNICATIONS option of the Main Menu (see "Main menu" in Section 3). For details on the programmable aspects of the interfaces, see "GPIB bus operation and reference; primary address" and "RS-232 operation."

NOTE *When changing interface selections, the SourceMeter performs a power-on reset. To check and/or change options of the selected interface, you must re-enter the menu structure.*

GPIB bus operation and reference

This section contains information about connecting to and using the GPIB (IEEE-488) bus. The information is organized as follows:

- GPIB bus standards
- GPIB bus connections
- Primary address selection
- QuickBASIC 4.5 programming
- General bus commands
- Front panel aspects of GPIB operation
- Status structure
- Trigger model
- Programming syntax
- Common commands

GPIB bus standards

The GPIB bus is the IEEE-488 instrumentation data bus with hardware and programming standards originally adopted by the IEEE (Institute of Electrical and Electronic Engineers) in 1975. The Model 2420 conforms to these standards:

- IEEE-488-1987.1
- IEEE-488-1987.2

This standard defines a syntax for sending data to and from instruments, how an instrument interprets this data, what registers should exist to record the state of the instrument, and a group of common commands.

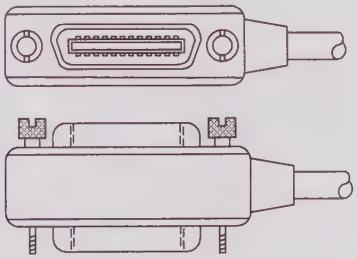
SCPI 1996 (Standard Commands for Programmable Instruments)

This standard defines a command language protocol. It goes one step farther than IEEE-488-1987.2 and defines a standard set of commands to control every programmable aspect of an instrument.

GPIB bus connections

To connect the Model 2420 to the GPIB bus, use a cable equipped with standard IEEE-488 connectors as shown in Figure 4-1.

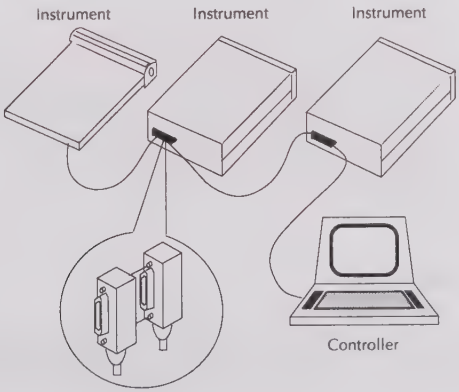
Figure 4-1
IEEE-488 connector



To allow many parallel connections to one instrument, stack the connector. Two screws are located on each connector to ensure that connections remain secure. Current standards call for metric threads, which are identified with dark-colored screws. Earlier versions have different screws, which are silver-colored. Do not use these types of connectors on the Model 2420 because it is designed for metric threads.

Figure 4-2 shows a typical connecting scheme for a multi-unit test system.

Figure 4-2
IEEE-488 connections



To avoid possible mechanical damage, stack no more than three connectors on any one unit.

NOTE *To minimize interference caused by electromagnetic radiation, use only shielded IEEE-488 cables. Available shielded cables from Keithley are models 7007-1 and 7007-2.*

To connect the Model 2420 to the IEEE-488 bus, follow these steps:

1. Line up the cable connector with the connector located on the rear panel. The connector is designed so it will fit only one way. Figure 4-3 shows the location of the IEEE-488 connector.
2. Tighten the screws securely, making sure not to over tighten them.
3. Connect any additional connectors from other instruments as required for your application.
4. Make sure the other end of the cable is properly connected to the controller. Most controllers are equipped with an IEEE-488 style connector, but a few may require a different type of connecting cable. See your controllers instruction manual for information about properly connecting to the IEEE-488 bus.

NOTE *You can only have 15 devices connected to a IEEE-488 bus, including the controller. The maximum cable length is either 20 meters or two meters multipled by the number of devices, whichever is less. Not observing these limits may cause erratic bus operation.*

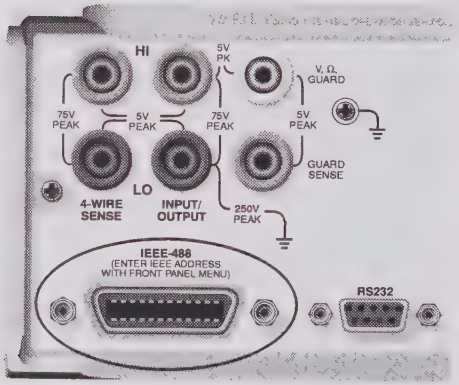


Figure 4-3 IEEE-488 connector location

Primary address

The Model 2420 ships from the factory with a GPIB address of 24. When the powers up, it momentarily displays the primary address. You can set the address to a value of 0 to 30. Do not assign the same address to another device or to a controller that is on the same GPIB bus.

Controller addresses are usually 0 or 21, but check the controller's instruction manual for details. Make sure the address of the controller is the same as that specified in the controller's programming language.

The primary address can be checked and/or changed from the COMMUNICATIONS option of the Main Menu (see "Main menu" in Section 3).

QuickBASIC 4.5 programming

Programming examples are written in Microsoft QuickBASIC 4.5 using the Keithley KPC488.2 (or Capital Equipment Corporation) IEEE interface and the HP-style Universal Language Driver (CECHP).

Universal language driver installation

Before any programming example can be run, the Universal Language Driver must first be installed. To install the driver, from the DOS prompt, enter this command:

```
cechp
```

If you include the CECHP command in your AUTOEXEC.BAT file, the driver will automatically be installed every time you turn on your computer.

Using program fragments

Program fragments are used to demonstrate proper programming syntax. As the name implies, only a fragment of the whole program is used to avoid redundancy.

At the beginning of each program, driver files must be opened. The input terminator should be set for LF. For example:

```
OPEN "ieee" FOR OUTPUT AS #1
OPEN "ieee" FOR INPUT AS #2
PRINT #1, "interm lf"
```

A typical program fragment includes an OUTPUT command and an ENTER command. The OUTPUT command sends a program message (command string) to the Model 2420. If the program message includes a query command, then the ENTER command is required to get the response message from the Model 2420. The ENTER command addresses the Model 2420 to talk. The following example program fragment demonstrates how OUTPUT and ENTER commands are used. Note that the commands assume address 24, which is the factory-set address of the Model 2420.

```
PRINT #1, "output 24; :trig:coun 10; coun?"
PRINT #1, "enter 24"
```

If you wish to display the response message on the CRT, the computer must read the message and then "print" it to the CRT display as follows:

```
LINE INPUT #2, A$
PRINT A$
```

The following programming example shows how all the previous statements are used together. The program fragment is shown in bold typeface.

```
OPEN "ieee" FOR OUTPUT AS #1                    ' Open driver
OPEN "ieee" FOR INPUT AS #2                     ' Open driver
PRINT #1, "interm lf"                           ' LF terminator
PRINT #1, "output 24; :trig:coun 10; coun?"     ' Set trigger count and query
PRINT #1, "enter 24"                            ' Get response message
LINE INPUT #2, A$                               ' Read response message
PRINT A$                                        ' Display message
```

General bus commands

General commands are those commands, such as DCL, that have the same general meaning regardless of the instrument. Table 4-1 lists the general bus commands along with the programming statement for each command, which uses the Keithley KPC-488.2 IEEE interface and the HP-style Universal Language Driver. Note that the commands that require the primary address to be specified assume that the address is the factory set address of 24.

Table 4-1
General bus commands and associated statements

Command	Programming statement	Effect on Model 2420
REN	REMOTE 24	Goes into effect when next addressed to listen.
IFC	ABORT	Goes into talker and listener idle states.
LLO	LOCAL LOCKOUT	LOCAL key locked out.
GTL	LOCAL 24	Cancel remote; restore front panel operation for the 2420.
	LOCAL	Cancel remote; restore front panel operation for all devices.
DCL	CLEAR	Returns all devices to known conditions.
SDC	CLEAR 24	Returns Model 2420 to known conditions.
GET	TRIGGER 24	Initiates a trigger.
SPE, SPD	SPOLL 24	Serial polls the Model 2420.

REN (remote enable)

The remote enable command is sent to the Model 2420 by the controller to set up the instrument for remote operation. Generally, the instrument should be placed in the remote mode before you attempt to program it over the bus. Setting REN true does not place the instrument in the remote state. You must address the instrument to listen after setting REN true before it goes into remote.

The SourceMeter must be in remote in order to use the following commands to trigger and acquire readings:

- :INITiate and then :FETCh?
- :READ?
- :MEASure?

Program fragment

```
PRINT #1, "remote 24"          'Place the Model 2420 in remote; turn on REM
                                annunciator
```

Note that all front panel controls except for LOCAL (and POWER) are inoperative while the instrument is in remote. You can restore normal front panel operation by pressing the LOCAL key.

IFC (interface clear)

The IFC command is sent by the controller to place the Model 2420 in the local, talker, listener idle states. The unit responds to the IFC command by canceling front panel TALK or LSTN lights, if the instrument was previously placed in one of these states.

Note that this command does not affect the status of the instrument. Settings, data, and event registers are not changed.

With auto output off enabled (:SOURce1:CLEar:AUTO ON), the output will remain on if operation is terminated before the output has a chance to automatically turn off.

To send the IFC command, the controller need only set the IFC line true for a minimum of 100µs.

Program fragment

```
PRINT #1, "output 24; *idn?"    ' Send query command
PRINT #1, "enter 24"            ' Read data; turn on TALK annunciator
SLEEP 3                         ' Wait 3 seconds
PRINT #1, "abort"               ' Talker idle state; turn off TALK annunciator
```

LLO (local lockout)

Use the LLO command to prevent local operation of the instrument. After the unit receives LLO, all of its front panel controls except OUTPUT OFF are inoperative. In this state, pressing LOCAL will not restore control to the front panel. The GTL command restores control to the front panel. Cycling power will also cancel local lockout.

Program fragment

```
PRINT #1, "remote 24"           ' Place 2420 in remote
PRINT #1, "local lockout"       ' Lock out front panel (including LOCAL key)
SLEEP 6                         ' Wait 6 seconds
PRINT #1, "local 24"            ' Restore front panel operation
```

GTL (go to local)

Use the GTL command to put a remote-mode instrument into local mode. The GTL command also restores front panel key operation.

Program fragment

```
PRINT #1, "remote 24"          ' Place 2420 in remote
SLEEP 3                        ' Wait 3 seconds
PRINT #1, "local 24"           ' Place 2420 in local mode
```

DCL (device clear)

Use the DCL command to clear the GPIB interface and return it to a known state. Note that the DCL command is not an addressed command, so all instruments equipped to implement DCL will do so simultaneously.

When the Model 2420 receives a DCL command, it clears the Input Buffer and Output Queue, cancels deferred commands, and clears any command that prevents the processing of any other device command. A DCL does not affect instrument settings and stored data.

Program fragment

```
PRINT #1, "clear"              ' Clear all devices
```

SDC (selective device clear)

The SDC command is an addressed command that performs essentially the same function as the DCL command. However, since each device must be individually addressed, the SDC command provides a method to clear only selected instruments instead of clearing all instruments simultaneously, as is the case with DCL.

Program fragment

```
PRINT #1, "clear 24"           ' Clear 2420
```

GET (group execute trigger)

GET is a GPIB trigger that is used as an arm event to control operation. The Model 2420 reacts to this trigger if it is the programmed arm control source. The following command selects the GPIB arm control source:

```
:ARM:SOURce  BUS
```

NOTE *With :ARM:SOURce BUS selected and an :INITiate command sent, do not send any commands (except GET, DCL, SDC, IFC, *TRG, and :ABORt) while performing source-measure operations (ARM annunciator on). If you do, erratic operation will occur.*

With the instrument programmed and waiting for a GPIB trigger, the following program fragment will provide the GET:

Program fragment

```
PRINT #1, "trigger 24"          ' Trigger 2420 from over the bus
```

This sends IEEE-488 commands UNT UNL LISTEN 24 GET. When the command is executed, the trigger event occurs. (The command TRIGGER only sends GET. Any other listeners are triggered when the command is executed.)

SPE, SPD (serial polling)

Use the serial polling sequence to obtain the Model 2420 serial poll byte. The serial poll byte contains important information about internal functions, (see "Status structure"). Generally, the serial polling sequence is used by the controller to determine which of several instruments has requested service with the SRQ line. However, the serial polling sequence may be performed at any time to obtain the status byte from the Model 2420.

Program fragment

```
PRINT #1, "spoll 24"            ' Serial poll the 2420
INPUT #2, S                     ' Read serial poll byte
PRINT S                         ' Display the decimal value of the serial poll byte
```

Front panel aspects of GPIB operation

This section describes aspects of the front panel that are part of GPIB operation, including messages, status indicators, and the LOCAL key.

Error and status messages

See Appendix B for a list of error and status messages associated with IEEE-488 programming. The instrument can be programmed to generate an SRQ, and command queries can be performed to check for specific error conditions.

GPIB status indicators

The REM (remote), TALK (talk), LSTN (listen), and SRQ (service request) annunciators show the GPIB bus status. Each of these indicators is described below.

REM — This indicator shows when the instrument is in the remote state. REM does not necessarily indicate the state of the REM line, as the instrument must be addressed to listen with REM true before the REM indicator turns on. When the instrument is in remote, all front panel keys, except for the LOCAL key, are locked out. When REM is turned off, the instrument is in the local state, and front panel operation is restored.

TALK — This indicator is on when the instrument is in the talker active state. Place the unit in the talk state by addressing it to talk with the correct MTA (My Talk Address) command. TALK is off when the unit is in the talker idle state. Place the unit in the talker idle state by sending an UNT (Untalk) command, addressing it to listen, or sending the IFC (Interface Clear) command.

LSTN — This indicator is on when the Model 2420 is in the listener active state, which is activated by addressing the instrument to listen with the correct MLA (My Listen Address) command. LSTN is off when the unit is in the listener idle state. Place the unit in the listener idle state by sending UNL (Unlisten), addressing it to talk, or sending IFC (Interface Clear) command over the bus.

SRQ — You can program the instrument to generate a service request (SRQ) when one or more errors or conditions occur. When this indicator is on, a service request has been generated. This indicator stays on until the serial poll byte is read or all the conditions that caused SRQ have ceased to exist. See "Status structure" for more information.

LOCAL key

The LOCAL key cancels the remote state and restores local operation of the instrument.

Pressing the LOCAL key also turns off the REM indicator and returns the display to normal if a user-defined message was displayed.

If the LLO (Local Lockout) command is in effect, the LOCAL key is also inoperative.

Status structure

Figure 4-4 shows the status structure for the SourceMeter. Instrument events, such as errors, are monitored and manipulated by four status register sets. Notice that these status register sets feed directly into the Status Byte Register. More detailed illustrations of these register sets are provided by Figures 4-5 through 4-8.

Condition registers

As Figure 4-4 shows, all status register sets have a condition register. A condition register is a real-time, read-only register that constantly updates to reflect the present operating conditions of the instrument. For example, while a sweep is being performed, bit B3 (Swp) of the Operation Condition Register is set. When the sweep is completed, bit B3 clears.

Use the :CONDition? query commands in the STATus Subsystem to read the condition registers. See Section 5 for more information.

Event registers

As Figure 4-4 shows, each status register set has an event register. An event register is a latched, read-only register whose bits are set by the corresponding condition register. Once a bit in an event register is set, it remains set (latched) until the register is cleared by a specific clearing operation. The bits of an event register are logically ANDed with the bits of the corresponding enable register and applied to an OR gate. The output of the OR gate is applied to the Status Byte Register.

Use the *ESR? Common Command to read the Standard Event Register. All other event registers are read using the :EVENt? query commands in the STATus Subsystem. See Section 5 for more information.

An event register is cleared when it is read. The following operations clear all event registers:

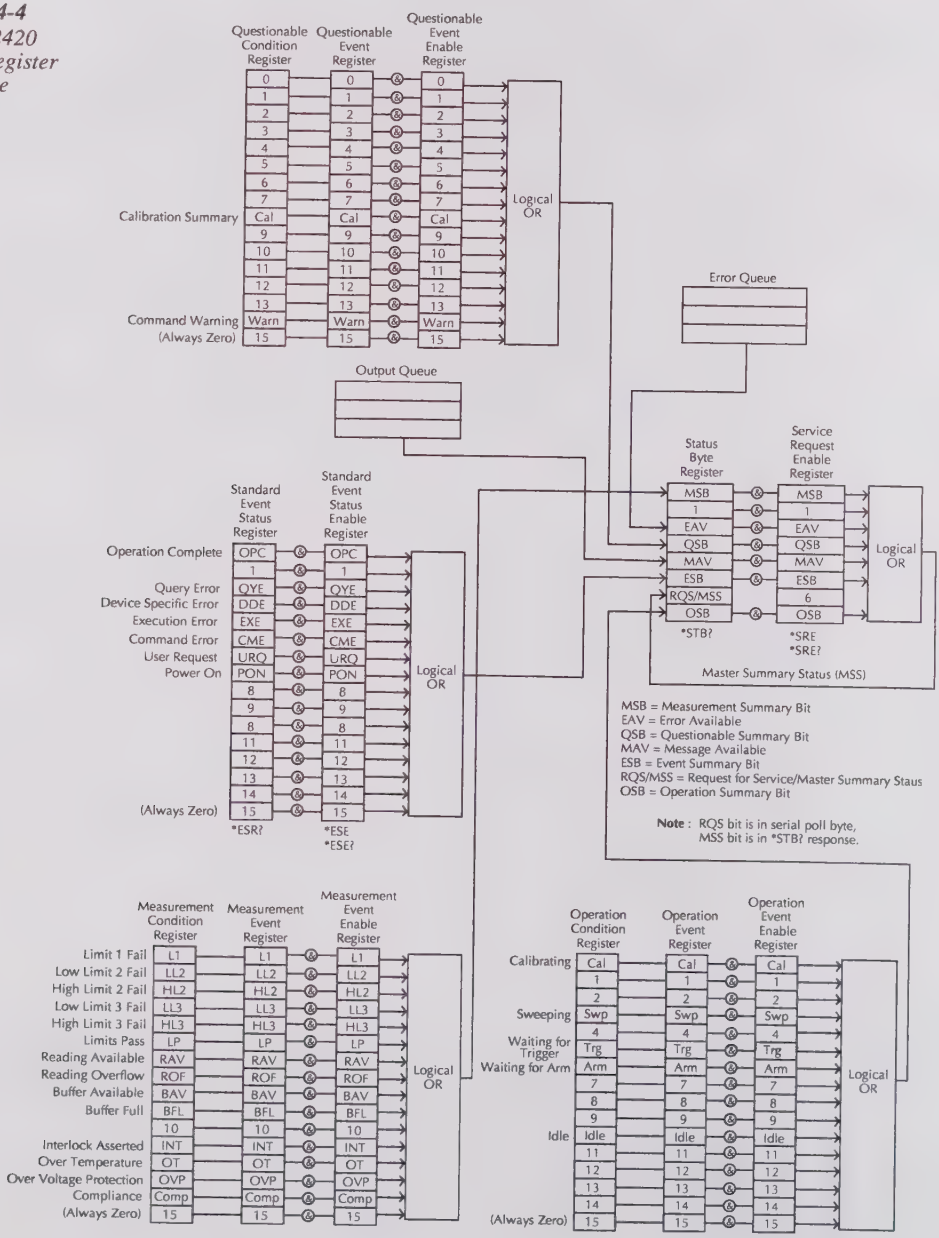
- Cycling power
- Sending *CLS

Enable registers

As Figure 4-4 shows, each status register set has an enable register. An enable register is programmed by you and serves as a mask for the corresponding event register. An event bit is masked when the corresponding bit in the enable register is cleared (0). When masked, a set bit in an event register cannot set a bit in the Status Byte Register (1 AND 0 = 0).

To use the Status Byte Register to detect events (i.e., serial poll), you must unmask the events by setting the appropriate bits of the enable registers.

Figure 4-4
Model 2420 status register structure



To program and query the Standard Event Status Register, use the *ESE and *ESE? Common Commands. All other enable registers are programmed and queried using the :ENABle and :ENABLe? commands in the STATus Subsystem. See Section 5 for more information.

An enable register is not cleared when it is read. The following operations affect the enable registers:

- Cycling power — Clears all enable registers
- :STATus:PRESet — Clears the following enable registers:
  Operation Event Enable Register
  Questionable Event Enable Register
  Measurement Event Enable Register
- *ESE 0 — Clears the Standard Event Status Enable Register.

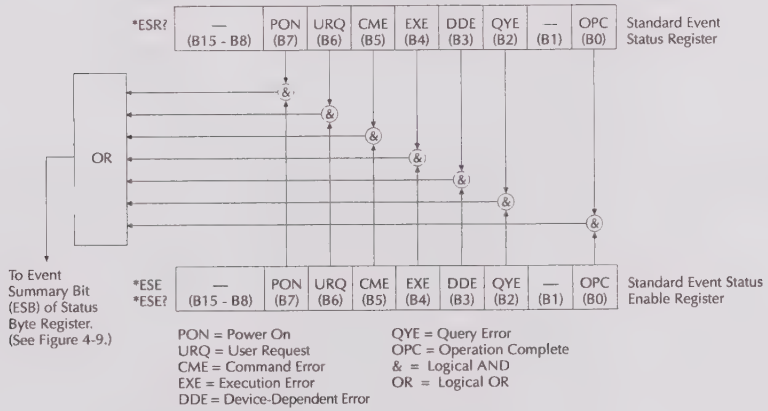


Figure 4-5
Standard event status

Figure 4-6
Operation event status

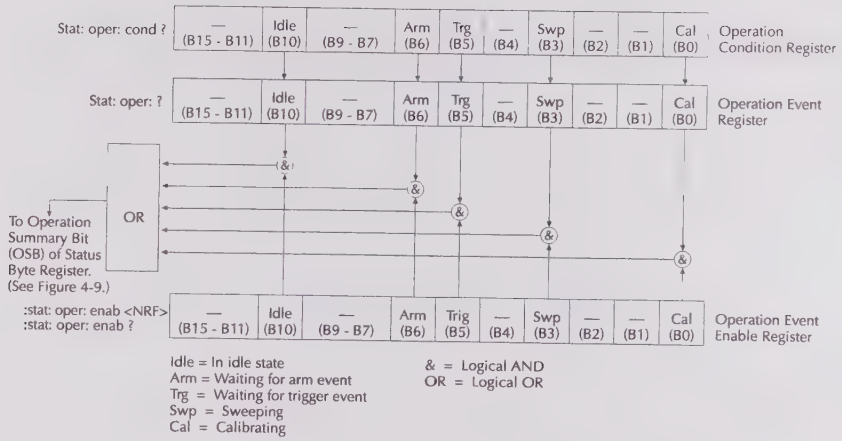


Figure 4-7
Measurement event status

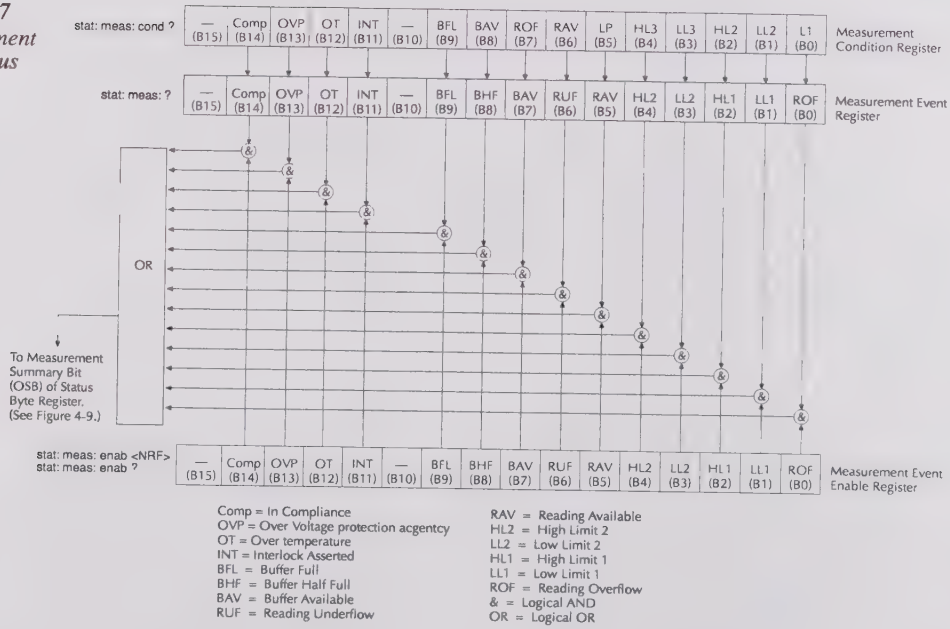
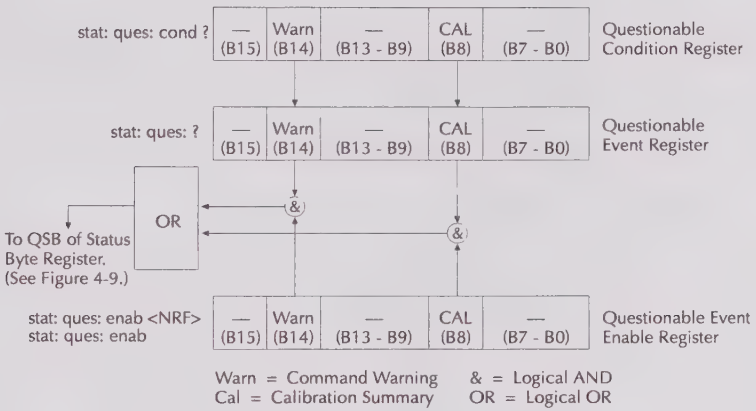


Figure 4-8
Questionable event status



Queues

The Model 2420 uses two queues, which are first-in, first-out (FIFO) registers:

- Output Queue — used to hold reading and response messages
- Error Queue — used to hold error and status messages

The Model 2420 status model (Figure 4-4) shows how the two queues are structured with the other registers.

Output Queue

The output queue holds data that pertains to the normal operation of the instrument. For example, when a query command is sent, the response message is placed in the Output Queue.

When data is placed in the Output Queue, the Message Available (MAV) bit in the Status Byte Register sets. A data message is cleared from the Output Queue when it is read. The Output Queue is considered cleared when it is empty. An empty Output Queue clears the MAV bit in the Status Byte Register.

Read a message from the Output Queue by addressing the Model 2420 to talk after the appropriate query is sent.

Error Queue

The Error Queue holds error and status messages. When an error or status event occurs, a message that defines the error/status is placed in the Error Queue. This queue will hold up to 10 messages.

When a message is placed in the Error Queue, the Error Available (EAV) bit in the Status Byte Register is set. An error message is cleared from the Error/Status Queue when it is read. The Error Queue is considered cleared when it is empty. An empty Error Queue clears the EAV bit

in the Status Byte Register. Read an error message from the Error Queue by sending either of the following SCPI query commands and then addressing the Model 2420 to talk:

- :SYSTem:ERRor?
- :STATus:QUEue?

See Section 5 for complete information about reading error messages.

Status Byte and Service Request (SRQ)

Service request is controlled by two 8-bit registers: the Status Byte Register and the Service Request Enable Register. Figure 4-9 shows the structure of these registers.

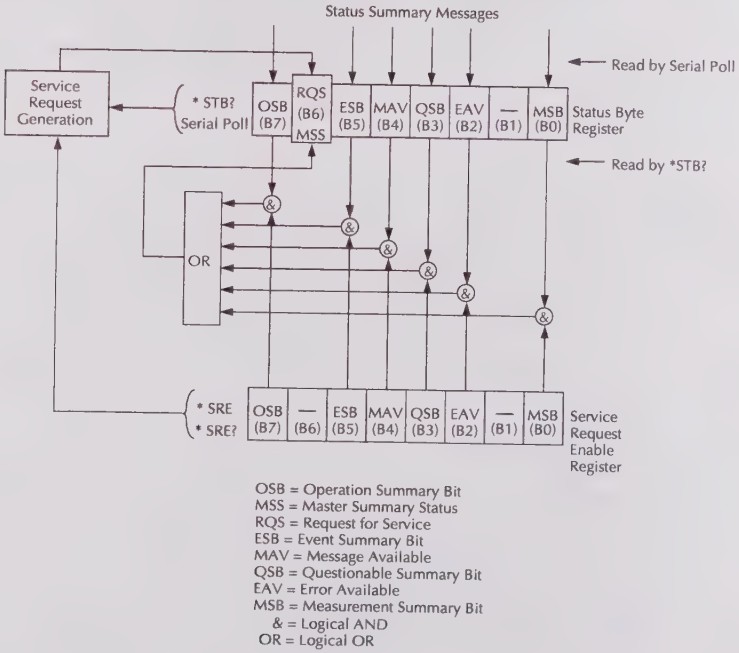


Figure 4-9
Status byte and service request (SRQ)

Status Byte Register — The summary messages from the status registers and queues are used to set or clear the appropriate bits (B0, B2, B3, B4, B5, and B7) of the Status Byte Register. These bits do not latch, and their states (0 or 1) are dependent on the summary messages (0 or 1). For example, if the Standard Event Status Register is read, its register will clear. As a result, its summary message will reset to 0, which in turn will clear the ESB bit in the Status Byte Register.

Bit B6 in the Status Byte Register is one of the following:

- The Master Summary Status (MSS) bit, sent in response to the *STB? command, indicates the status of any set bits with corresponding enable bits set.
- The Request for Service (RQS) bit, sent in response to a serial poll, indicates which device was requesting service by pulling on the SRQ line.

For a description of the other bits in the Status Byte Register, see "Common commands, *STB?".

The IEEE-488.2 standard uses the *STB? common query command to read the Status Byte Register.

When reading the Status Byte Register using the *STB? command, bit B6 is called the MSS bit. None of the bits in the Status Byte Register are cleared when using the *STB? command to read it.

The IEEE-488.1 standard has a serial poll sequence that also reads the Status Byte Register and is better suited to detect a service request (SRQ). When using the serial poll, bit B6 is called the RQS bit. Serial polling causes bit B6 (RQS) to reset. Serial polling is discussed in more detail later in this section.

Either of the following operations clears all bits of the Status Byte Register:

- Cycling power.
- Sending the *CLS common command

NOTE *The MAV bit may or may not be cleared.*

Service Request Enable Register — This register is programmed by you and serves as a mask for the Status Summary Message bits (B0, B2, B3, B4, B5, and B7) of the Status Byte Register. When masked, a set summary bit in the Status Byte Register cannot set bit B6 (MSS/RQS) of the Status Byte Register. Conversely, when unmasked, a set summary bit in the Status Byte Register sets bit B6.

A Status Summary Message bit in the Status Byte Register is masked when the corresponding bit in the Service Request Enable Register is cleared (0). When the masked summary bit in the Status Byte Register sets, it is ANDed with the corresponding cleared bit in the Service Request Enable Register. The logic "1" output of the AND gate is applied to the input of the OR gate and thus sets the MSS/RQS bit in he Status Byte Register.

The individual bits of the Service Request Enable Register can be set or cleared by using the *SRE <NRf> common command.

To read the Service Request Enable Register, use the *SRE? query command. The Service Request Enable Register clears when power is cycled or a parameter (n) value of zero is sent with the *SRE command (*SRE 0).

Serial poll and SRQ — Any enabled event summary bit that goes from 0 to 1 will set RQS and generate a service request (SRQ). In your test program, you can periodically read the Status Byte Register to check if a service request (SRQ) has occurred and what caused it. If an SRQ occurs, the program can, for example, branch to an appropriate subroutine that will service the request. Typically, service requests (SRQs) are managed by the serial poll sequence of the Model 2420. If an SRQ does not occur, bit B6 (RQS) of the Status Byte Register will remain cleared, and the program will proceed normally after the serial poll is performed. If an SRQ does occur, bit B6 of the Status Byte Register will set, and the program can branch to a service subroutine when the SRQ is detected by the serial poll.

The serial poll automatically resets RQS of the Status Byte Register. This allows subsequent serial polls to monitor bit B6 for an SRQ occurrence generated by other event types. After a serial poll, the same event can cause another SRQ, even if the event register that caused the first SRQ has not been cleared.

A serial poll clears RQS but does not clear MSS. The MSS bit stays set until all Status Byte event summary bits are cleared.

The following QuickBASIC 4.5 program (using the KPC-488.2 interface and the CECHP driver) demonstrates how serial poll can be used to detect an SRQ:

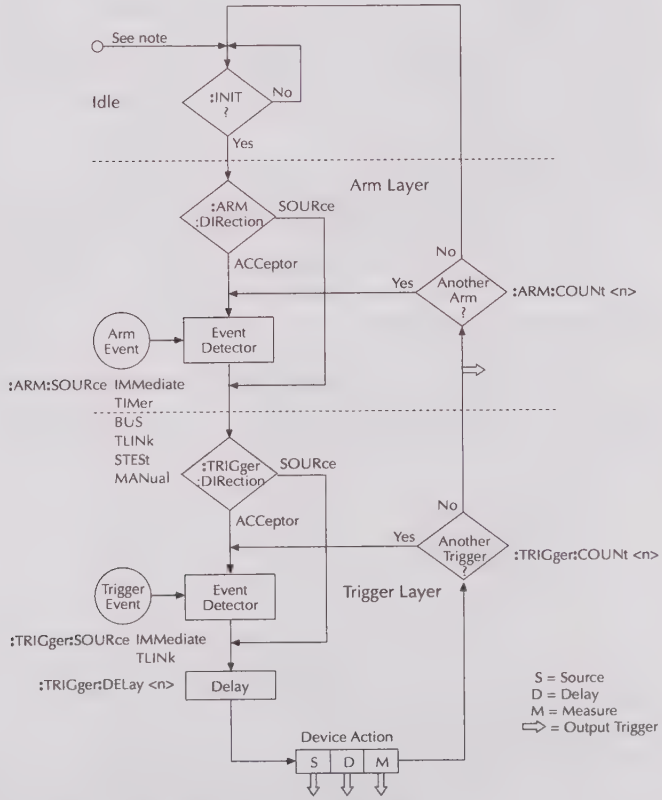
```
CLS
OPEN "ieee" FOR OUTPUT AS #1
OPEN "ieee" FOR INPUT AS #2
PRINT #1, "output 24; *cls"          ' Clear Status Byte Register
PRINT #1, "output 24; *ese 32"       ' Unmask command errors
PRINT #1, "output 24; *sre 32"       ' Unmask event summary message
PRINT #1, "output 24; *ese"          ' Error - missing parameter
SLEEP 1
PRINT #1, "SPOLL 24"                 ' Serial poll 2420
INPUT #2, S                          ' Read Status Byte Register
S=S OR 191                           ' OR register with a mask
IF S= 255 THEN
GOSUB srq                            ' Go to subroutine to acknowledge SRQ
END IF
PRINT
END

srq:
PRINT "SRQ Has Occurred--RQS (bit B6) is set (1)"
RETURN
```

Trigger model (remote operation)

The trigger model flowchart in Figure 4-10 summarizes operation over the bus. Operation is controlled by SCPI commands from the Trigger subsystem (see Section 5 for more information). Key SCPI commands are included in the trigger model.

Figure 4-10
Trigger model (remote operation)



Note: The following commands place the SourceMeter into idle: DCL, SDC, :ABORT, *RST, :SYSTem: PRESet, and *RCL.

Idle and initiate

The instrument is considered to be in the idle state (ARM annunciator off) when it is not operating within the trigger model layers. While in the idle state, the instrument cannot perform any measurements. An initiate command is required to take the instrument out of idle. The following commands perform an initiate operation:

- :INITiate
- :READ?
- :MEASure?

When auto output-off is disabled (:SOURce1:CLEar:AUTO OFF), you must first turn the source output on before sending the :INITiate or :READ? command. The :MEASure? command will automatically turn the output on. Note that after the instrument returns to the idle state, the output will remain on.

When auto output-off is enabled (:SOURce1:CLEar:AUTO ON), any of the above three commands can be used to initiate operation. The source output will automatically turn on at the beginning of each SDM (source-delay-measure) cycle and turn off after each measurement is completed.

While operating within the trigger model (ARM annunciator on), most commands will not be executed until the SourceMeter completes all of its programmed source-measure operations and returns to the idle state.

The IFC, SDC, and DCL commands can be executed under any circumstances while operating within the trigger model. They will abort any other command or query.

The following commands can be executed while operating within the trigger model except when a READ? or MEASure? is being processed:

- :ABORt
- :SYSTem:PRESet
- *TRG or GET
- *RST
- *RCL

NOTE *SDC, DCL, or :ABORt places the SourceMeter in the idle state. For fastest response, use SDC or DCL to return to idle.*

Trigger model operation

Once the instrument is taken out of idle, operation proceeds through the trigger model down to the device action. In general, the device action is the source-measure operation of the instrument.

Event detectors

As shown in Figure 4-10, control sources are used to hold up operation until the programmed event occurs. If, however, a source bypass is being used (:DIRection SOURce), operation will loop around the control source on each pass through the trigger model.

The control source options are explained as follows:

- **IMMediate** — Event detection for the arm and trigger layers is satisfied immediately, allowing operation to continue.
- **MANual** — Event detection for the arm layer is satisfied by pressing the TRIG key. The Model 2420 must be in LOCAL mode for it to respond to the TRIG key. Press the LOCAL key or send LOCAL 24 over the bus to remove the instrument from the remote mode.

- **TIMer** — Event detection for the arm layer is immediately satisfied on the initial pass through the trigger model. Each subsequent detection is satisfied when the programmed timer interval (0.001 to 99999.99 seconds) elapses. The timer resets to its initial state when the instrument goes into the idle state.
- **TLINk** — Event detection for the arm and trigger layers is satisfied when an input trigger via the TRIGGER LINK connector is received by the Model 2420.
- **BUS** — Event detection for the arm layer is satisfied when a bus trigger (GET or *TRG) is received by the Model 2420.
- **STESt** — Event detection is satisfied when the start of test (/SOT) strobe is received from a handler (see "Limit testing" in Section 2).

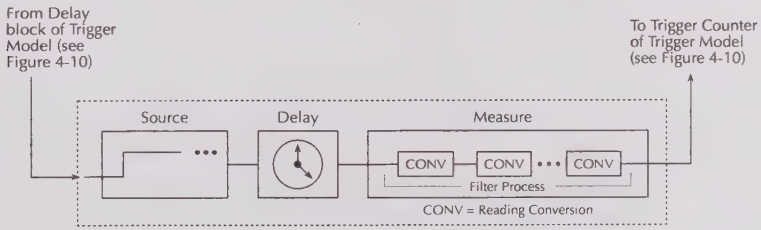
Delay

A programmable delay is available after trigger event detection and before the device action. The delay can be manually set from 0.0000 to 999.9999 seconds. Note that this delay is separate from the delay used in the SDM cycle (see Device Action).

Device action

The device action is the SDM (Source-Delay-Measure) cycle of the instrument and is shown in Figure 4-11.

Figure 4-11
Device action (SDM cycle)



Source — Assuming the source is turned on, any programmed output voltage or current level changes are performed. Note that the instrument can be programmed to output a trigger pulse after the source phase of the device action (see "Output triggers").

Delay — This programmable delay is used to allow the source to settle before a measurement is performed. It can be manually set from 0.0000 to 999.9999 seconds using the :SOURce:DELay <n> command, or Auto Delay can be enabled using the :SOURce:DELay:AUTO <b> command. With Auto Delay enabled, the instrument automatically selects a nominal delay period based on the selected function and range.

The instrument can be programmed to output a trigger pulse after the delay phase of the device action (see "Output triggers").

Measure — During this phase of the SDM cycle, the measurement process takes place. If the repeat filter is enabled, then the instrument samples the specified number of reading conversions to yield a single filtered reading (measurement). If using the moving filter or if the filter is disabled, then only a single reading conversion will yield a reading (measurement).

The instrument can be programmed to output a trigger after the measure phase of the device action (see "Output triggers").

Output triggers

The Model 2420 can be programmed to output trigger pulses. These output trigger pulses are applied to the Trigger Link connector on the rear panel and are typically used to trigger an external instrument to perform an operation.

You can program the instrument to output a trigger pulse after the source, delay and/or measure phase of the Device Action, and/or when operation leaves the trigger layer and re-enters the arm layer. Output triggers are programmed using the :OUTPut command in the Trigger subsystem.

Counters

Programmable counters are used to repeat operations within the trigger model layers. For example, if performing a 10-point sweep, the trigger counter would be set to 10.

Operation will stay in the trigger layer until the 10 source-measure points of the sweep are performed. If you wanted to repeat the sweep three times, the arm counter would be set to three. Three 10-point sweeps can then be performed for a total of 30 source-measure actions.

The maximum buffer size for the SourceMeter is 2500 readings. Thus, the product of the two counters cannot exceed 2500. For example, if you set an arm count of two, the maximum trigger count will be 1250 (2500/2).

Operation summary

The trigger model is designed to offer versatility for the various source-measure applications. Typically, it allows you to perform a specified number of measurements at various source levels.

For example, assume you want to perform three measurements each at two different V-source levels (1V and 2V). To do this set the arm count for two (arm:count 2) and the trigger count for three (trigger:count 3), and use the list sourcing mode with the following defined list:

:sour:list:volt 1, 1, 1, 2, 2, 2

On the first pass through the trigger model, three measurements will be performed at the 1V source level. On the second pass, three measurements will be performed at the 2V source level. After the last measurement, the SourceMeter returns to the idle state. Note that the product of the arm count and trigger count determines the number of measurements that are performed. In this example, six measurements are performed (2×3).

For details on the list sourcing mode, see the SOURce Subsystem in Section 5.

Programming syntax

The information in this section covers syntax for both common commands and SCPI commands. For information not covered here, see the IEEE- 488.2 and SCPI standards.

Command words

Program messages are made up of one or more command words.

Commands and command parameters

Common commands and SCPI commands may or may not use a parameter. The following are some examples:

*SAV <NRf>	Parameter (NRf) required
*RST	No parameter used
:CALCulate1:STATe <b>	Parameter <b> required
:SYSTem:PRESet	No parameter used.

NOTE *At least one space between the command word and the parameter is required.*

Brackets [ ] — Some command words are enclosed in brackets ([ ]). These brackets are used to denote an optional command word that does not need to be included in the program message. For example:

:INITiate[:IMMediate]

These brackets indicate that :IMMediate is implied (optional) and does not have to used. Thus, the above command can be sent in one of two ways:

:INITiate

or

:INITiate:IMMediate

Notice that the optional command is used without the brackets. When using optional command words in your program, do not include the brackets.

Parameter types — The following are some of the more common parameter types:

<b> Boolean — Used to enable or disable an instrument operation. 0 or OFF disables the operation, and 1 or ON enables the operation. Example:

:CALCulate1:STATe ON Enable Calc 1 math expression

<name> Name parameter — Select a parameter name from a listed group. Example:

<name> = NEVer
= NEXt

:TRACe:FEED:CONTrol NEXt

<NRf> Numeric representation format — This parameter is a number that can be expressed as an integer (e.g., 8), a real number (e.g., 23.6), or an exponent (2.3E6). Example:

```
:SYSTem:KEY 11          Press EXIT key from over the bus
```

<NDN> Non-decimal numeric — This parameter is used to send values in the binary, octal, or hexadecimal format. The prefix designates the format type:

```
#Bxx...x        #B specifies the binary format.
                xx...x is the binary number
                (using 0s and 1s).
#Qxx...x        #Q specifies the octal format.
                xx...x is the octal number
                (values 0 through 7).
#Hxx...x        #H specifies the hexadecimal format
                xx...x is the hexadecimal number
                (values 0 through 9, and A through F).
```

Examples to send the decimal value 36 in the non-decimal formats:

```
*ESE #b100100       Binary format
*ESE #q44           Octal format
*ESE #h24           Hexadecimal format
```

<n> Numeric value — A numeric value parameter can consist of an NRf number or one of the following name parameters: DEFault, MINimum, MAXimum. When the DEFault parameter is used, the instrument is programmed to the *RST default value. When the MINimum parameter is used, the instrument is programmed to the lowest allowable value. When the MAXimum parameter is used, the instrument is programmed to the largest allowable value. Examples:

```
:ARM:TIMer 0.1          Sets timer to 100 msec.
:ARM:TIMer DEFault      Sets timer to 0.1 sec.
:ARM:TIMer MINimum      Sets timer to 1 msec.
:ARM:TIMer MAXimum      Sets timer to 99999.99 sec.
```

<numlist> Numlist — Specify one or more numbers for a list. Example:

```
:STATus:QUEue:ENABle (-110:-222)    Enable errors -110 thru -222
```

Angle Brackets < > — Angle brackets (< >) are used to denote a parameter type. Do not include the brackets in the program message. For example:

```
:OUTPut <b>
```

The <b> indicates a Boolean-type parameter is required. Therefore, to enable the selected source, you must send the command with the ON or 1 parameter as follows:

```
:OUTPut ON
:OUTPut 1
```

Query commands

This type of command requests (queries) the presently programmed status. It is identified by the question mark (?) at the end of the fundamental form of the command. Most commands have a query form, Example:

:ARM:TIMer?	Queries the timer interval.

Most command that require a numeric parameter(<n>) can also use the DEFault, MINimum, and MAXimum parameters for the query form. These query forms are used to determine the *RST default value and the upper and lower limits for the fundamental command. Examples:

:ARM:TIMer? DEFault	Queries the *RST default value.
:ARM:TIMer? MINimum	Queries the lowest allowable value.
:ARM:TIMer? MAXimum	Queries the largest allowable value.

Case sensitivity

Common commands and SCPI commands are not case sensitive. You can use upper or lower case and any case combination. Examples:

*RST	= *rst
:DATA?	= :data?
:SYSTem:PRESet	= :system:preset

Long-form and short-form versions

A SCPI command word can be sent in its long-form or short-form version. The command subsystem tables in Section 5 provide the in the long-form version. However, the short-form version is indicated by upper case characters. Examples:

:SYSTem:PRESet	long-form
:SYST:PRES	short form
:SYSTem:PRES	long-form and short-form combination

Note that each command word must be in long-form or short-form, and not something in between. For example, :SYSTe:PRESe is illegal and will generate an error. The command will not be executed.

Short-form rules

Use the following rules to determine the short-form version of any SCPI command:

- If the length of the command word is four letters or less, no short form version exists. Example:

  :auto = :auto

These rules apply to command words that exceed four letters:

- If the fourth letter of the command word is a vowel (including "y"), delete it and all the letters after it. Example

  :immediate = :imm

- If the fourth letter of the command word is a consonant, retain it but drop all the letters after it. Example:

  :format = :form

- If the command contains a question mark (?; query) or a non-optional number included in the command word, you must include it in the short-form version. Example:

  :delay? = :del?

- Command words or characters that are enclosed in brackets ([ ]) are optional and need not be included in the program message.

Program messages

A program message is made up of one or more command words sent by the computer to the instrument. Each common command is a three letter acronym preceded by an asterisk (*). SCPI commands are categorized in the :STATus subsystem and are used to explain how command words are structured to formulate program messages.

```
:STATus                 Path (Root)
  :OPERation              Path
    :ENABle <NRf>           Command and parameter
    :ENABle?                Query command
  :PRESet                 Command
```

Single command messages

The above command structure has three levels. The first level is made up of the root command (:STATus) and serves as a path. The second level is made up of another path (:OPERation) and a command (:PRESet). The third path is made up of one command for the :OPERation path. The three commands in this structure can be executed by sending three separate program messages as follows:

```
:stat:oper:enab <NRf>
:stat:oper:enab?
:stat:pres
```

In each of the above program messages, the path pointer starts at the root command (:stat) and moves down the command levels until the command is executed.

Multiple command messages

You can send multiple command messages in the same program message as long as they are separated by semicolons (;). The following is an example showing two commands in one program message:

:stat:oper; :stat:oper:enab <NRf>

When the above is sent, the first command word is recognized as the root command (:stat). When the next colon is detected, the path pointer moves down to the next command level and executes the command. When the path pointer sees the colon after the semicolon (;), it resets back to the root level and starts over.

Commands that are on the same command level can be executed without having to retype the entire command path. Example:

:stat:oper:enab <NRf>; enab?

After the first command (:enab) is executed, the path pointer is at the third command level in the structure. Since :enab? is also on the third level, it can be typed in without repeating the entire path name. Notice that the leading colon for :enab? is not included in the program message. If a colon were included, the path pointer would reset to the root level and expect a root command. Since :enab? is not a root command, an error would occur.

Command path rules

- Each new program message must begin with the root command, unless it is optional (e.g., [:SENSe]). If the root is optional, simply treat a command word on the next level as the root.
- The colon (:) at the beginning of a program message is optional and need not be used. Example:

  :stat:pres = stat:pres

- When the path pointer detects a colon (:) it moves down to the next command level. An exception is when the path pointer detects a semicolon (;), which is used to separate commands within the program message (see next rule).
- When the path pointer detects a colon (:) that immediately follows a semicolon (;), it resets back to the root level.
- The path pointer can only move down. It cannot be moved up a level. Executing a command at a higher level requires that you start over at the root command.

Using Common and SCPI commands in the same message

Both common commands and SCPI commands can be used in the same message as long as they are separated by semicolons (;). A common command can be executed at any command level and will not affect the path pointer. Example:

:stat:oper:enab <NRf>; *ESE <NRf>

Program message terminator (PMT)

Each program message must be terminated with an LF (line feed), EOI (end or identify), or an LF+EOI. The bus will hang if your computer does not provide this termination. The following example shows how a multiple command program message must be terminated:

:outp on <PMT>

Command execution rules

- Commands execute in the order that they are presented in the program message.
- An invalid command generates an error and, of course, is not executed.
- Valid commands that precede an invalid command in a multiple command program message are executed.
- Valid commands that follow an invalid command in a multiple command program message are ignored.

Response messages

A response message is the message sent by the instrument to the computer in response to a query command program message.

Sending a response message

After sending a query command, the response message is placed in the Output Queue. When the Model 2420 is then addressed to talk, the response message is sent from the Output Queue to the computer.

Multiple response messages

If you send more than one query command in the same program message (see "Multiple command messages"), the multiple response messages for all the queries are sent to the computer when the Model 2420 is addressed to talk. The responses are sent in the order the query commands were sent and are separated by semicolons (;). Items within the same query are separated by commas (,). The following example shows the response message for a program message that contains four single item query commands:

0; 1; 1; 0

Response message terminator (RMT)

Each response is terminated with an LF (line feed) and EOI (end or identify). The following example shows how a multiple response message is terminated:

0; 1; 1; 0 <RMT>

Message exchange protocol

Two rules summarize the message exchange protocol:

Rule 1. You must always tell the Model 2420 what to send to the computer.

The following two steps must always be performed to send information from the instrument to the computer:

1. Send the appropriate query command(s) in a program message.
2. Address the Model 2420 to talk.

Rule 2. The complete response message must be received by the computer before another program message can be sent to the Model 2420.

Common commands

Common commands (summarized in Table 4-2) are device commands that are common to all devices on the bus. These commands are designated and defined by the IEEE-488.2 standard.

Table 4-2
IEEE-488.2 common commands and queries

Mnemonic	Name	Description
*CLS	Clear status	Clears all event registers and Error Queue.
*ESE <NRf>l,<NDN>	Event enable command	Programs the Standard Event Enable Register.
*ESE?	Event enable query	Reads the Standard Event Enable Register.
*ESR?	Event status register query	Reads the Standard Event Enable Register and clears it.
*IDN?	Identification query	Returns the manufacturer, model number, serial number, and firmware revision levels of the unit.
*OPC	Operation complete command	Sets the Operation Complete bit in the Standard Event Status Register after all pending commands have been executed.
*OPC?	Operation complete query	Places an ASCII "1" into the output queue when all pending selected device operations have been completed.
*RCL <NRf>	Recall command	Returns the Model 2420 to the setup configuration stored in memory.
*RST	Reset command	Returns the Model 2420 to the *RST default conditions.
*SAV <NRf>	Save command	Saves the present setup in memory.
*SRE <NRf>l<NDN>	Service request enable command	Programs the Service Request Enable Register.
*SRE?	Service request enable query*	Reads the Service Request Enable Register.
*STB?	Status byte query*	Reads the Status Byte Register.
*TRG	Trigger command	Sends a bus trigger to the 2420.
*TST?	Self-test query	Performs a checksum test on ROM and returns the result.
*WAI	Wait-to-continue command	Waits until all previous commands are executed.

* The response message format depends on the format selected by :FORMat:SREGister (binary, octal, decimal, or hexadecimal).

*CLS — Clear Status

Clear status registers and error queue

Description

Use the *CLS command to clear (reset to 0) the bits of the following registers in the Model 2420:

- Standard Event Register
- Operation Event Register
- Error Queue
- Measurement Event Register
- Questionable Event Register

This command also forces the instrument into the operation complete command idle state and operation complete query idle state.

*ESE <NDN> or <NRf> — Event Enable

Program the standard event enable register

*ESE? — Event Enable Query

Read the standard event register

Parameters

<NDN>	=	#Bxx...x	Binary format (x = 1 or 0)
		#Qxx...x	Octal format (x = 0 through 7)
		#Hxx...x	Hexadecimal format (x = 0 through 9, A through F)
<NRf>	=	0 to 255	Decimal (ASCII) format
		where:	0 clears register
			255 sets all bits

Description

Use the *ESE command to program the Standard Event Enable Register (see Figure 4-12). This command is sent with a value that determines the desired state (0 or 1) of each bit in the register. The *ESE? command is used to read this register. This register is cleared on power-up.

This register is used as a mask for the Standard Event Register. When a standard event is masked, the occurrence of that event will not set the Event Summary Bit (ESB) in the Status Byte Register. Conversely, when a standard event is unmasked (enabled), the occurrence of that event sets the ESB bit. For information on the Standard Event Register and descriptions of the standard event bits see the *ESR? command.

A cleared bit (0) in the enabled register prevents (masks) the ESB bit in the Status Byte Register from setting when the corresponding standard event occurs. A set bit (1) in the enable register allows (enables) the ESB bit to set when the corresponding standard event occurs.

This register can be programmed using a binary, octal, decimal, or hexadecimal parameter value. As shown in "Parameters," the decimal format uses an <NRf> parameter type, and the other formats use an <NDN> type.

Use Figure 4-12 to determine the parameter value for the command. For example, if you wish to set bits B4, B3, and B1 of the enable register, the binary value would be 11010 (where B4=1, B3=1, B2=0, B1=1, and B0=0). If you wish to use one of the other formats, convert the binary number to its octal, decimal, or hexadecimal equivalent.

Note that the decimal weight of each bit is included in Figure 4-12. To determine the decimal parameter value, add the decimal weights of each bit you wish to set. For binary 11010, the decimal equivalent is 26 (16+8+2).

The following examples show proper syntax for settings bits B5 and B2.

*ESE #b100100	(binary format, <NDN> parameter)
*ESE #q44	(octal format, <NDN> parameter)
*ESE #h24	(hexadecimal format, <NDN> parameter)
*ESE 36	(decimal format, <NRf> parameter)

If a command error (CME) occurs, bit B5 of the Standard Event Status Register sets. If a query error (QYE) occurs, bit B2 of the Standard Event Status Register sets. Since both of these events are unmasked (enabled), the occurrence of any one of them causes the ESB bit in the Status Byte Register to set.

Note that the value returned by ESE? will be in the binary, octal, decimal, or hexadecimal format. The response message value format for this query command is set using the :FORMat:SREGister command (see FORMat Subsystem).

.

Figure 4-12
Standard event enable register

Bit Position	B7	B6	B5	B4	B3	B2	B1	B0
Event	PON	URQ	CME	EXE	DDE	QYE	—	OPC
Decimal Weighting	128 (2^7)	64 (2^6)	32 (2^5)	16 (2^4)	8 (2^3)	4 (2^2)	—	1 (2^0)
Value	0/1	0/1	0/1	0/1	0/1	0/1	—	0/1

Note : Bits B8 through B15 are not shown since they are not used.

Value : 1 = Enable Standard Event
0 = Disable (Mask) Standard Event

Events : PON = Power On
URQ = User Request
CME = Command Error
EXE = Execution Error
DDE = Device-dependent Error
QYE = Query Error
OPC = Operation Complete

*ESR? — Event Status Register Query

Read the standard event status register and clear it

Description

This query command is used to read the Standard Event Status Register (see Figure 4-13). After sending this command and addressing the Model 2420 to talk, a value is sent to the computer. This value indicates which bits in the register are set. A set bit indicates that a particular event has occurred.

The response message will be returned as a binary, octal, decimal, or hexadecimal value. The value format is set using the :FORMat:SREGister command (see FORMat subsystem).

If a binary value is returned, the value indicates which bits are set. For example, for a binary value of 110101, bits B5, B4, B2, and B0 are set. Bits B3 and B1 are clear. For the other formats, convert the octal, decimal, or hexadecimal value to its binary equivalent.

The bits of the Standard Event Status Register are described as follows:

- Bit B0, Operation Complete — A set bit indicates that all pending selected device operations are completed and the Model 2420 is ready to accept new commands. This bit only sets in response to the *OPC? query command.
- Bit B1 — Not used
- Bit B2, Query Error (QYE) — A set bit indicates that you attempted to read data from an empty Output Queue.
- Bit B3, Device-dependent Error (DDE) — A set bit indicates that an instrument operation did not execute properly due to some internal condition.
- Bit B4, Execution Error (EXE) — A set bit indicates that the Model 2420 detected an error while trying to execute a command.
- Bit B5, Command Error (CME) — A set bit indicates that a command error has occurred. Command errors include:

  –IEEE-488.2 syntax error: Model 2420 received a message that does not follow the defined syntax of the IEEE-488.2 standard.

  –Semantic error: Model 2420 received a command that was misspelled, or received an optional IEEE-488.2 command that is not implemented.

  –The instrument received a Group Execute Trigger (GET) inside a program message
- Bit B6, User Request (URQ) — A set bit indicates that the LOCAL key on the Model 2420 front panel was pressed.
- Bit B7, Power ON (PON) — A set bit indicates that the Model 2420 has been turned off and turned back on since the last time this register has been read.

Figure 4-13
Standard event status register

Bit Position	B7	B6	B5	B4	B3	B2	B1	B0
Event	PON	URQ	CME	EXE	DDE	QYE	—	OPC
Decimal Weighting	128 (2^7)	64 (2^6)	32 (2^5)	16 (2^4)	8 (2^3)	4 (2^2)	—	1 (2^0)
Value	0/1	0/1	0/1	0/1	0/1	0/1	—	0/1

Note : Bits B8 through B15 are not shown since they are not used.

Value : 1 = Event Bit Set
0 = Event Bit Cleared

Events : PON = Power On
URQ = User Request
CME = Command Error
EXE = Execution Error
DDE = Device-dependent Error
QYE = Query Error
OPC = Operation Complete

*IDN? — Identification Query **Read the identification code**

Description The identification code includes the manufacturer, model number, serial number, and firmware revision levels, and is sent in the following format:

KEITHLEY INSTRUMENTS INC., MODEL 2420, xxxxxxx, yyyyy/zzzzz/a/d

Where: xxxxxxx is the serial number.
yyyyy is the firmware revision level (and date and time) of the digital board ROM.
zzzzz is the firmware revision level of the display board ROM.
a is the analog board revision level.
d is the digital board revision level.

*OPC — Operation Complete

Set the OPC bit in the standard event status register after all pending commands are complete

Description

When this command is sent, the OPC bit in the standard event status register will set after all pending commands are complete.

Typically, this command is sent after the :INITiate command. The :INITiate command is used to take the SourceMeter out of idle (ARM annunciator on) in order to perform source-measure operations. Remember that while operating within the trigger model, all commands (except DCL, SDC, IFC, .:SYSTem: PRESet, *RST, *RCL, *TRG, GET, and :ABORt) that are sent are not executed.

After all programmed source-measure operations are completed, the SourceMeter returns to the idle state at which time all pending commands (including the *OPC command) are executed. After the last pending command is executed, the OPC bit will set.

*OPC? — Operation Complete Query

Place a "1" in the output queue after all pending operations are completed

Description

When this command is sent, an ASCII "1" is placed in the output queue after all pending operations are completed.

Typically, this command is sent after the :INITiate command. The :INITiate command is used to take the SourceMeter out of idle (ARM annunciator on) in order to perform source-measure operations. Remember that while operating within the trigger model layers, all commands (except DCL, SDC, IFC, :SYSTem: PRESet, *RST, *RCL, GET, *TRG and :ABORt) that are sent are not executed.

After all programmed source-measure operations are completed, the SourceMeter returns to the idle state at which time all pending commands (including the *OPC? command) are executed. After the last pending command is executed, "1" is placed in the output queue.

*RCL — Recall

Return to setup stored in memory

Parameters

<Nrf> =	0	Return to saved setup configuration at memory location 0
	1	Return to saved setup configuration at memory location 1
	2	Return to saved setup configuration at memory location 2
	3	Return to saved setup configuration at memory location 3
	4	Return to saved setup configuration at memory location 4

Description

Use this command to return the Model 2420 to the configuration stored at the specified memory location (0 to 4). The *SAV command is used to store the setup configuration in memory.

The Model 2420 ships from the factory with :SYSTem:PRESet defaults loaded into the available setup memory. If a recall error occurs, the setup memory defaults to the :SYSTem:PRESet values.

*RST — RESet

Return 2420 to *RST defaults

Description

When the *RST command is sent, the Model 2420 performs the following operations:

- Returns the Model 2420 to the *RST default conditions (see SCPI tables).
- Cancels all pending commands.
- Cancels response to any previously received *OPC and *OPC? commands.

*SAV — Save

Save present setup in memory

Parameters

<NRf> =0		Save setup at memory location 0
	1	Save setup at memory location 1
	2	Save setup at memory location 2
	3	Save setup at memory location 3
	4	Save setup at memory location 4

Description

Use the *SAV command to save the present instrument setup configuration in memory for later recall. Up to five setup configurations can be saved.

Any control affected by *RST can be saved by the *SAV command. The *RCL command is used to restore the instrument to the saved setup configuration.

*SRE <NDN> or <NRf> — Service Request Enable — Program register
*SRE? — Service Request Enable Query — Read register

Parameters

<NDN>	=	#Bxx...x	Binary format (x = 1 or 0)
		#Qxx...x	Octal format (x = 0 through 7)
		#Hxx...x	Hexadecimal format (x = 0 through 9, A through F)
<NRf>	=	0 to 255	Decimal (ASCII) format
		where:	0 clears register 255 sets all bits

Description

Use the *SRE command to program the Service Request Enable Register (see Figure 4-14). This command is sent with a value that determines the desired state (0 to 1) of each bit in the register. The *SRE? command is used to read this register. This register is cleared on power-up.

This enable register is used along with the Status Byte Register to generate service requests (SRQ). With a bit in the Service Request Enable Register set, an SRQ occurs when the corresponding bit in the Status Byte Register is set by an appropriate event. For more information on register structure, see the information presented earlier in this section.

This register can be programmed using a binary, octal, decimal, or hexadecimal parameter value. As shown in "Parameters," the decimal format uses an <NRf> parameter type, and the other formats use an <NDN> type.

Use Figure 4-14 to determine the parameter value for the command. For example, if you wish to set bits B4, B3, and B0 of the enable register, the binary value would be 11001 (where B4=1, B3=1, B2=0, B1=0, and B0=1). If you wish to use one of the other formats, convert the binary number to its octal, decimal, or hexadecimal equivalent.

Note that the decimal weight of each bit is included in Figure 4-14. To determine the decimal parameter value, add the decimal weights of each bit you wish to set. For binary 11001, the decimal equivalent is 25 (16+8+1).

The following examples show proper syntax for settings B5, B3, and B2.

*ESE #b101100	(binary format, <NDN> parameter)
*ESE #q54	(octal format, <NDN> parameter)
*ESE #h2C	(hexadecimal format, <NDN> parameter)
*ESE 44	(decimal format, <NRf> parameter)

Note that the value returned by ESR? will be in the binary, octal, decimal, or hexadecimal format. The response message value format for this query command is set using the :FORMat:SREGister command (see FORMat Subsystem).

Figure 4-14
Service request enable register

Bit Position	B7	B6	B5	B4	B3	B2	B1	B0
Event	OSB	—	ESB	MAV	QSB	EAV	—	MSB
Decimal Weighting	128 (2^7)	—	32 (2^5)	16 (2^4)	8 (2^3)	4 (2^2)	—	1 (2^0)
Value	0/1	—	0/1	0/1	0/1	0/1	—	0/1

Value : 1 = Enable Service Request Event
0 = Disable (Mask) Service Request Event

Events : OSB = Operation Summary Bit
ESB = Event Summary Bit
MAV = Message Available
QSB = Questionable Summary Bit
EAV = Error Available
MSB = Measurement Summary Bit

*STB? — Status Byte Query

Read status byte register

Description

This query command is used to read the Status Byte Register (see Figure 4-15). After sending this command and addressing the Model 2420 to talk, a value is sent to the computer. This value indicates which bits in the register are set. All bits except B6 are set by other event registers and queues. Bit 6 sets when one or more enabled conditions occur.

The response message will be returned as a binary, octal, decimal, or hexadecimal value. The value format is set using the :FORMat:SREGister command (see FORMat subsystem).

If a binary value is returned, the value itself indicates which bits are set. For example, for a binary value of 110101, bits B5, B4, B2, and B0 are set. Bits B3 and B1 are clear. For the other formats, convert the octal, decimal, or hexadecimal value to its binary equivalent.

The *STB? command does not clear the Status Byte Register. This register can only be cleared by clearing the related registers and queues. See "Status structure" for details.

Figure 4-15
Status byte register

Bit Position	B7	B6	B5	B4	B3	B2	B1	B0
Event	OSB	MSS, RQS	ESB	MAV	QSB	EAV	—	MSB
Decimal Weighting	128 (2^7)	64 (2^6)	32 (2^5)	16 (2^4)	8 (2^3)	4 (2^2)	—	1 (2^0)
Value	0/1	0/1	0/1	0/1	0/1	0/1	—	0/1

Value : 1 = Event Bit Set
0 = Event Bit Cleared

Events : OSB = Operation Summary Bit
MSS = Master Summary Status
RQS = Request Service
ESB = Event Summary Bit
MAV = Message Available
QSB = Questionable Summary Bit
EAV = Error Available
MSB = Measurement Summary Bit

The bits of the Status Byte Register are described as follows:

- Bit 0, Measurement Status (MSB) — A set bit indicates that a measurement event has occurred. The event can be identified by reading the Measurement Event Status Register using the :STATus:MEASurement? command (see Section 5 for details).
- Bit 1 — Not used.
- Bit 2, Error Available (EAV) — A set bit indicates that an error or status message is present in the Error Queue. The message can be read using one of the following SCPI commands:

  :SYSTem:ERRor?
  :STATus:QUEue?

  See Section 5 for more information.
- Bit 3, Questionable Summary Bit (QSB) — A set bit indicates that a calibration error has occurred.
- Bit 4, Message Available (MAV) — A set bit indicates that a message is present in the Output Queue. The message is sent to the computer when the Model 2420 is addressed to talk.
- Bit 5, Event Summary Bit (ESB) — A set bit indicates that an enabled standard event has occurred. The event can be identified by reading the Standard Event Status Register using the *ESE? query command.
- Bit 6, Master Summary Status (MSS)/Request Service (RQS) — A set bit indicates that one or more enabled Status Byte conditions have occurred. Read the MSS bit by using the STB? query command, or perform a serial poll to detect the occurrence of a service request (RQS bit set).
- Bit 7, Operation Summary (OSB) — A set bit indicates that an enabled operation event has occurred. The event can be identified by reading the Operation Event Status Register using the :STATus:OPERation? query command (see Section 5 for details).

*TRG — Trigger

Send bus trigger to 2420

Description

Use the *TRG command to issue a GPIB trigger to the Model 2420. It has the same effect as a group execute trigger (GET).

Use the *TRG command as an event to control operation. The Model 2420 reacts to this trigger if BUS is the programmed arm control source. The following command selects the GPIB arm control source:

:ARM:SOURce BUS

NOTE: With :ARM:SOURce BUS selected, do not send any commands (except *TRG, GET, DCL, SDC, IFC, and :ABORt) while performing source-measure operations (ARM annunciator on). If you do, erratic operation will occur.

*TST? — Self-Test Query

Run self test and read result

Description

Use this query command to perform a checksum test on ROM. The command places the coded result (0 or 1) in the Output Queue. When the Model 2420 is addressed to talk, the coded result is sent from the Output Queue to the computer.

A returned value of zero (0) indicates that the test passed, and a value of one (1) indicates that the test has failed.

*WAI — Wait-to-Continue

Wait until previous commands are completed

Description

Note that the *WAI command is a No Op (no operation) for the Model 2420 and therefore does not need to be used.

There are two types of device commands:

- Sequential commands — A command whose operations are allowed to finish before the next command is executed.
- Overlapped commands — A command that allows the execution of subsequent commands while device operations of the Overlapped command are still in progress.

The *WAI command is used to suspend the execution of subsequent commands until the device operations of all previous Overlapped commands are finished. The *WAI command is not needed for Sequential commands.

RS-232 operation

NOTE *The programmable aspects of RS-232 operation (baud rate, data bits, parity, and terminator are configured from the COMMUNICATION option of the Main Menu (see "Main menu" in Section 3).*

Sending and receiving data

The RS-232 interface transfers data using 8 data bits, 1 stop bit, and no parity. Make sure the device you connect to the also uses these settings.

You can break data transmissions by sending a decimal 3 or 18 character string to the instrument. This clears any pending operation and discards any pending output.

Baud rate

The baud rate is the rate at which the Model 2420 and the programming terminal or printer communicate. Choose one these available rates:

- 19.2k
- 9600
- 4800
- 2400
- 1200
- 600
- 300

The factory selected baud rate is 9600.

When you choose a baud rate, make sure the programming terminal or printer that you are connecting to the Model 2420 can support the baud rate you selected. Both the Model 2420 and the other device must be configured for the same baud rate.

Data Bits and Parity

The RS-232 interface can be configured to send/receive data that is 7 or 8 bits long using even, odd, or no parity. No parity is only valid when using 8 data bits.

Terminator

The Model 2420 can be configured to terminate each program message that it transmits to the controller with any of the following combinations of <CR> and <LF>:

<CR>	Carriage return
<CR+LF>	Carriage return and line feed
<LF>	Line feed
<LF+CR>	Line feed and carriage return

Flow control (signal handshaking)

Signal handshaking between the controller and the instrument lets the two devices communicate with each other about readiness to receive data. The Model 2420 does not support hardware handshaking (flow control).

Software flow control is in the form of XON and XOFF characters and is enabled when XON-XOFF is selected from the RS232 FLOW CONTROL menu. When the input queue of the Model 2420 becomes more than 3/4 full, the instrument issues an XOFF command. The control program should respond to this and stop sending characters until the Model 2420 issues the XON, which it will do once its input buffer has dropped below half-full. The Model 2420 recognizes XON and XOFF sent from the controller. An XOFF will cause the Model 2420 to stop outputting characters until it sees an XON. Incoming commands are processed after the <CR> character is received from the controller.

If NONE is the selected flow control, there will be no signal handshaking between the controller and the Model 2420. Data will be lost if transmitted before the receiving device is ready.

RS-232 connections

The RS-232 serial port is connected to the serial port of a computer or listening device (i.e., serial printer) using a straight through RS-232 cable terminated with DB-9 connectors. Do not use a null modem cable. The serial port uses the transmit (TXD), receive (RXD), and signal ground (GND) lines of the RS-232 standard. Figure 4-16 shows the rear panel connector for the RS-232 interface, and Table 4-3 shows the pinout for the connector.

If your computer uses a DB-25 connector for the RS-232 interface, you will need a cable or adapter with a DB-25 connector on one end and a DB-9 connector on the other, wired straight through (not null modem).

Figure 4-16
RS-232 interface connector

Table 4-3
RS-232 connector pinout

Pin number	Description
1	Not used
2	TXD, transmit data
3	RXD, receive data
4	Not used
5	GND, signal ground
6	Not used
7	CTS, clear to send
8	RTS, ready to send
9	Not used

NOTE: CTS and RTS are tied together.

Table 4-4 provides inout identification for the 9-pin (DB-9) or 25-pin (DB-25) serial port connector on the computer (PC).

Table 4-4
PC serial port pinout

Signal	DB-9 pin number	DB-25 pin number
DCD, data carrier detect	1	8
RXD, receive data	2	3
TXD, transmit data	3	2
DTR, data terminal ready	4	20
GND, signal ground	5	7
DSR, data set ready	6	6
RTS, request to send	7	4
CTS, clear to send	8	5
RI, ring indicator	9	22

Error messages

See Appendix B for RS-232 error messages.

5
SCPI Command Reference

Introduction

This section contains reference information on programming the Model 2420 with the SCPI commands. It is organized as follows:

- SCPI Signal Oriented Measurement Commands — Covers the signal oriented measurement commands. These commands are used to acquire readings.
- SCPI command subsystems reference tables — Includes a summary table for each SCPI subsystem command.
- SCPI command subsystems — Includes additional information on each SCPI subsystem command.

SCPI signal oriented measurement commands

The signal oriented measurement commands are used to acquire readings. You can use these high-level instructions to control the measurement process. These commands are summarized in Table 5-1.

Table 5-1
Signal oriented measurement command summary

Command	Description
:CONFigure:<function>	Configures 2420 for measurements on specified function. Output turns on.
:FETCh?	Requests latest readings.
:READ?	Performs an :INITiate and a :FETCh?.
:MEASure[:<function>]?	One-shot measurement mode. Performs a :CONFigure and a :READ?.

Configure measurement function

:CONFigure:<function>

Parameters

<function> =	:CURRent[:DC]	Amps function
	:VOLTage[:DC]	Volts function
	:RESistance	Ohms function

Description This command configures the instrument to a specific setup for measurements on the specified function. The :READ? command is then typically used to trigger a specified number of measurements (see :READ?).

When this command is sent, the Model 2420 will be configured as follows:

- Select specified function.
- All controls related to the selected function are defaulted to the *RST values.
- The event control sources of the Trigger Model is set to Immediate.
- The count values of the Trigger Model are set to one.
- The Delay of the Trigger Model is set to zero.
- All math calculations are disabled.
- Buffer operation is disabled.
- Autozero is enabled.
- The source output will turn on.

WARNING **When :CONFigure is sent, the output will turn on. Beware of hazardous voltage that may be present on the output terminals.**

NOTE *This command is automatically asserted when the :MEASure? command is sent.*

Acquire readings

:FETCh?

Description This query command requests the latest post-processed readings stored in the sample buffer (see "Data Flow" in Appendix D). After sending this command and addressing the Model 2420 to talk, the readings are sent to the computer. This command does not affect the instrument setup.

This command does not trigger source-measure operations; it simply requests the last available readings. Note that this command can repeatedly return the same readings. Until there are new readings, this command continues to return the old readings. For example, assume that the SourceMeter performed 20 source-measure operations. The :FETCh? command will request the readings for those 20 source-measure operations. If :FETCh? is sent while performing source-measure operations (ARM annunciator on), it will not be executed until the SourceMeter goes back into idle.

The readings that are acquired depend on which data elements are selected (see :FORMat:ELEMents in the FORMat Subsystem), and what the instrument is presently programmed to source-measure. Measure readings take priority over source readings, and functions not sourced or measured are assigned the NAN (not a number) value of +9.91e37.

For example, assume that voltage, current and resistance readings are selected as data elements, and the instrument is programmed to Source V and Measure I. A reading string acquired by :FETch? will include the programmed V-Source value and the I-Measure reading. The reading for resistance will be NAN since resistance was not measured.

If the SourceMeter is instead programmed to Source V and Measure V, the voltage reading will be the V-Measure reading (not the programmed V-Source value). Both current and resistance readings will be NANs (current is not measured or sourced).

NOTE *The :FETCh? command is automatically asserted when the :READ? or :MEASure? command is sent.*

NOTE *See "Data Flow" in Appendix D for a detailed explanation on how data flows through the various operation blocks of the SourceMeter. It clarifies the type of readings that are acquired by the various commands to read data.*

:READ?

Description This command is used to trigger and acquire readings. The number of readings depends on how the trigger model is configured. For example, if configured for 20 source-measure operations (arm count 1, trigger count 20), then 20 sets of readings will be acquired after the SourceMeter returns to the idle state.

When this command is sent, the following commands execute in the order that they are presented:

- :INITiate
- :FETCh?

The :INITiate command starts operation by taking the instrument out of idle.

After all source-measure operations are completed, the SourceMeter goes back into idle at which time the :FETCh? command is executed. The readings are sent to the computer and displayed when the Model 2420 is addressed to talk.

Note that if auto output-off is disabled (:SOURce1:CLEar:AUTO OFF), then the output must be turned on before you can perform a :READ?. The output will then remain on after all source-measure operations are completed.

If auto output-off is enabled (:SOURce1:CLEar:AUTO ON), then the output will automatically turn on at the beginning of each SDM (source-delay-measure) cycle and turn off after each measurement.

NOTE *See "Data flow" in Appendix D for a detailed explanation on how data flows through the various operation blocks of the SourceMeter. It clarifies the type of readings that are acquired by the various commands to read data.*

:MEASure[:<function>]?

Parameters

<function> =	CURRent[:DC]	Amps function
	VOLTage[:DC]	Volts function
	RESistance	Ohms function

Description

This command combines other signal oriented measurement commands to perform a "one-shot" measurement and acquire the reading. Note that if a function is not specified, the measurement will be done on the function that is presently selected.

When this command is sent, the following commands execute in the order that they are presented.

- :CONFigure:<function>
- :READ?

When :CONFigure is executed, the instrument goes into a "one-shot" measurement mode. See :CONFigure for more details.

When :READ? is executed, its operations will then be performed. In general, another :ABORt is performed, then an :INITiate, and finally a FETCh? to acquire the readings. See :READ? for more details.

When :MEASure? is sent, the source turns on and a single measurement is performed. If auto output-off is enabled (:SOURce1:CLEar:AUTO ON), then the output will turn off after the measurement is completed. If auto output-off is disabled (:SOURce1:CLEar:AUTO OFF), then the output will remain on after the measurement is completed.

WARNING **With auto output-off disabled, the output will remain on after the one-shot source-measure operation is performed. Beware of hazardous voltage that may be present on the output terminals.**

SCPI command subsystems

Reference tables

Tables 5-2 through 5-11 summarize the commands for each SCPI subsystem. The following list includes the SCPI subsystem commands and the table number where each command is summarized.

Table 5-2 CALCulate command summary
Table 5-3 DISPlay command summary
Table 5-4 FORMat command summary
Table 5-5 OUTPut command summary
Table 5-6 ROUTe command summary
Table 5-7 SENSe command summary
Table 5-8 SOURce command summary
Table 5-9 STATus command summary
Table 5-10 SYSTem command summary
Table 5-11 TRACe command summary
Table 5-12 Trigger command summary

General notes:

- Brackets ([ ]) are used to denote optional character sets. These optional characters do not have to be included in the program message. Do not use brackets in the program message.
- Angle brackets (< >) are used to indicate parameter type. Do not use angle brackets in the program message.
- The Boolean parameter (<b>) is used to enable or disable an instrument operation. 1 or ON enables the operation, and 0 or OFF disables the operation.
- Upper case characters indicate the short-form version for each command word.
- Default Parameter — Listed parameters are both the *RST and :SYSTem:PRESet defaults, unless noted otherwise. Parameter notes are located at the end of each table.
- SCPI — A checkmark (√) indicates that the command and its parameters are SCPI confirmed. An unmarked command indicates that it is a SCPI command, but does not conform to the SCPI standard set of commands. It is not a recognized command by the SCPI consortium. SCPI confirmed commands that use one or more non-SCPI parameters are explained by notes.

Table 5-2
CALCulate command summary

Command	Description	Default parameter	SCPI
:CALCulate[1]	Subsystem to control CALC1:		√
:MATH	Path to configure and control math expressions:		√
[:EXPRession] <form>	Define math expression using standard math operator symbols.		√
			√
[:EXPRession]?	Query math expression.		√
:CATalog?	Query list of math expression names.		√
:NAME <name>	Create name for new user-defined expression.	POWER	√
:NAME?	Query created name.		√
[:DEFine] <form>	Same as :EXPRession <form> command.		√
:DELete	Path to delete user-defined expressions.		√
[:SELected] <name>	Delete specified expression.		√
:ALL	Delete all user-defined expressions.		√
:UNITs <name>	Define units name for math expression (3 ASCII characters).	"W"	
:UNITs?	Query math expression units name.		
:STATe <b>	Enable or disable math expression.	OFF	√
:STATe?	Query state of math expression.		√
:DATA?	Read result of math expression.		√
:CALCulate2	Subsystem to control CALC2:		√
:FEED <name>	Select input path: CALCulate[1], CURRent, VOLTage, or RESistance.	VOLT	√
:FEED?	Query CALC2 feed.		√
:NULL	Path to configure and control REL:		
:OFFSet <NRf>	Specify REL value (-9.999999e20 to 9.999999e20).	0	
:OFFSet?	Query REL value.		
:STATe <b>	Enable or disable REL.	OFF	
:STATe?	Query state of REL.		
:DATA?	Read math result of CALC2.		√
:LIMit[1]	Path to control LIMIT 1 test:		√
:COMPliance	Configure Limit 1 test:		
:FAIL <name>	Specify "fail" condition; IN or OUT of compliance.	IN	
:FAIL?	Query "fail" condition.		
:SOURce2 <NRf>	Specify four-bit output "fail" pattern (0 to 15).	15	
:SOURce2?	Query "fail" bit pattern.		
:STATe <b>	Enable or disable Limit 1 test.	OFF	√
:STATe?	Query state of Limit 1 test.		√
:FAIL?	Returns result of Limit 1 test: 0 (pass) or 1 (fail).		√
:LIMit2	Path to control LIMIT 2 test:		√
:UPPer	Configure upper limit:		√
[:DATA] <n>	Specify upper limit (-9.999999e20 to 9.999999e20).	1	√

Table 5-2 (cont.)
CALCulate command summary

Command	Description	Default parameter	SCPI
[:DATA]?	Query upper limit.		√
:SOURce2 <NRf>	Specify four-bit output "fail" pattern (0 to 15).	0	
:SOURce2?	Query "fail" bit pattern.		
:LOWer	Configure lower limit:		√
[:DATA] <n>	Specify lower limit (-9.999999e20 to 9.999999e20).	-1	√
[:DATA]?	Query lower limit.		√
:SOURce2 <NRf>	Specify four-bit output "fail" pattern (0 to 15).	0	
:SOURce2?	Query "fail" bit pattern.		
:STATe <b>	Enable or disable Limit 2 test.	OFF	√
:STATe?	Query state of Limit 2 test.		√
:FAIL?	Return result of Limit 2 test: 0 (pass) or 1 (fail).		√
:LIMit3	Path to control LIMIT 3 test:		√
:UPPer	Configure upper limit:		√
[:DATA] <n>	Specify upper limit (-9.999999e20 to 9.999999e20).	1	√
[:DATA]?	Query upper limit.		√
:SOURce2 <NRf>	Specify four-bit output "fail" pattern (0 to 15).	15	
:SOURce2?	Query "fail" bit pattern.		
:LOWer	Configure lower limit:		√
[:DATA] <n>	Specify lower limit (-9.999999e20 to 9.999999e20).	-1	√
[:DATA]?	Query lower limit.		√
:SOURce2 <NRf>	Specify four-bit output "fail" pattern (0 to 15).	15	
:SOURce2?	Query "fail" bit pattern.		
:STATe <b>	Enable or disable Limit 3 test.	OFF	√
:STATe?	Query state of Limit 3 test.		√
:FAIL?	Return result of Limit 3 test: 0 (pass) or 1 (fail).		√
:CLIMits	Composite limits:		√
:BCONtrol <name>	Specify when to send binning info to handler; after a limit test is performed (IMM) or after a sweep, list, or memory sequence (END).	IMM	
:BCONtrol?	Query binning control.		
:CLEar	Clear test results:		
[:IMMediate]	Clear latest limit test result and reset Digital I/O port back to :SOURce2:TTL settings.		
:AUTO <b>	Enable or disable clearing of test results when :INITiate command is sent.	ON	
:AUTO?	Query state of auto clear.		
:PASS	Define "pass" digital output pattern:		
:SOURce2 <NRf>	Specify four-bit output "pass" pattern (0 to 15).	15	
:SOURce2?	Query "pass" bit pattern.		
:SMLocation <NRf> | NEXT	Specify next "PASS" Source Memory Sweep location: NEXT location or 1 to 100.	NEXT	
:SMLocation?	Query "PASS" memory location.		

Table 5-2 (cont.)
CALCulate command summary

Command	Description	Default parameter	SCPI
:CALCulate3	Subsystem to control CALC3:		√
:FORMat <name>	Specify math format (MEAN, SDEViation, MAXimum, MINimum or PKPK).	MEAN	√
:FORMat?	Query math format.		√
:DATA?	Read math result of CALC3.		√

Table 5-3
DISPlay command summary

Command	Description	Default parameter	SCPI
:DISPlay			
:ENABle <b>	Turn on or turn off front panel display.	(Note 1)	√
:ENABle?	Query state of display.		√
:CNDisplay	Return to source-measure display state.		
[:WINDow[1]]	Path to locate message to top display:		√
:TEXT	Control user test message:	(Note 2)	√
:DATA <a>	Define ASCII message "a" (up to 20 characters).		√
:DATA?	Query text message.		√
:STATe <b>	Enable or disable message mode.	(Note 3)	√
:STATe?	Query text message state.		√
:DATA?	Query data on top portion of display.		
:ATTRibutes?	Query attributes of message characters: blinking (1) or not blinking (0).		
:WINDow2	Path to locate message to bottom display:		√
:TEXT	Control user test message:	(Note 2)	√
:DATA <a>	Define ASCII message "a" (up to 32 characters).		√
:DATA?	Query text message.		√
:STATe <b>	Enable or disable message mode.	(Note 3)	√
:STATe?	Query text message state.		√
:DATA?	Query data on bottom portion of display.		
:ATTRibutes?	Query attributes of message characters: blinking (1) or not blinking (0).		
:DIGits <n>	Specify display resolution (4 to 7).	6	
:DIGits?	Query display resolution		

Notes:
1. *RST and :SYSTem:PRESet has no effect on the display circuitry. Pressing LOCAL or cycling power enables (ON) the display circuit.
2. *RST and :SYSTem:PRESet has no effect on a user-defined message. Pressing LOCAL or cycling power cancels all user-defined messages.
3. *RST and :SYSTem:PRESet has no effect on the state of the message mode. Pressing LOCAL or cycling power disables (OFF) the message mode.

Table 5-4
FORMat command summary

Command	Description	Default parameter	SCPI
:FORMat			
[:DATA] <type>[<,length>]	Specify data format (ASCII, REAL,32 or SREAL).	ASCII	√
[:DATA]?	Query data format.		√
:BORDer <name>	Specify byte order (NORMal or SWAPped).	(see note)	√
:BORDer?	Query byte order.		√
:ELEMents <item list>	Specify data elements (VOLTage, CURRent, RESistance, TIME, and STATus).	All	
:ELEMents?	Query data format elements.		
:SREGister <name>	Select data format for reading status event registers (ASCii, HEXadecimal, OCTal, or BINary).	ASCii	√
:SREGister?	Query format for reading status event registers.		

NOTE: Byte order — *RST default is NORMal. :SYSTem:PRESet default is SWAPped.

Table 5-5
OUTPut command summary

Command	Description	Default parameter	SCPI
:OUTPut[1]			√
:STATe <b>	Turn source on or off.	OFF	√
:STATe?	Query state of source.		√
:INTerlock	Path to control interlock:		
:STATe <b>	Enable or disable interlock.	OFF	
:STATe?	Query state of interlock.		
:TRIPped?	Interlock tripped?: 1 (yes) or 0 (no)		
:SMODe <name>	Select output off mode (HIMPedance, NORMal, ZERO, or GUARd).	NORMAL	
:SMODe?	Query output off mode.		

Table 5-6
ROUTe command summary

Command	Description	Default parameter	SCPI
:ROUTe			
:TERMinals <name>	Select in/out terminals (FRONt or REAR).	FRONt	√
:TERMinals?	Query in/out terminals.		

Table 5-7
SENSe command summary

Command	Description	Default parameter	SCPI
[:SENSe[1]]	Sense 1 Subsystem:		√
:FUNCtion	Select measurement function(s):		√
:CONCurrent <b>	Enable or disable ability to measure more than one function simultaneously. When disabled, volts function is enabled.	ON	√
:CONCurrent?	Query concurrent state.		√
[:ON] <function list>	Specify functions to enable (VOLTage[:DC], CURRent[:DC] or RESistance).	CURRent	√
:ALL	Enable all functions (concurrent enabled) or enable ohms function (concurrent disabled).		√
:COUNt?	Query number of functions that are enabled.		√
[:ON]?	Returns list of functions that are enabled.		√
:OFF <function list>	Specify functions to disable (VOLTage[:DC], CURRent[:DC] or RESistance).	VOLTage, RESistance	√
:ALL	Disable all measurement functions.		√
:COUNt?	Query number of functions that are disabled.		√
:OFF?	Returns list of functions that are disabled.		√
:STATe? <name>	Query state of specified function: 1 (on) or 0 (off).		√
:CURRent[:DC]	Path to configure current:		√
:RANGe	Configure measurement range:		√
[:UPPer] <n>|UP|DOWN	Select range; 0 to ±3.15.	1.05e-4	√
[:UPPer]?	Query range.		√
:AUTO <b>	Enable or disable auto range.	ON	√
:AUTO?	Query auto range.		√
:NPLCycles <n>	Specify integration rate (in line cycles): 0.01 to 10.	1.0	√
:NPLCycles?	Query integration rate.		√
:PROTection	Path to configure current compliance:		√
[:LEVel] <n>	Specify current limit for V-Source (-3.15 to 3.15).	1.05e-4	√
[:LEVel]?	Query current compliance limit		√
:TRIPped?	In current compliance?: 1 (yes), 0 (no).		√

Table 5-7 (cont.)
SENSe command summary

Command	Description	Default parameter	SCPI
[:SENSe[1]]			
:VOLTage[:DC]	Path to configure volts:		√
:RANGe	Configure measurement range:		√
[:UPPer] <n>|UP|DOWN	Select range; 0 to 63.	21	√
[:UPPer]?	Query range.		√
:AUTO <b>	Enable or disable auto range.	ON	√
:AUTO?	Query auto range.		√
:NPLCycles <n>	Specify integration rate (in line cycles): 0.01 to 10.	1.0	√
:NPLCycles?	Query integration rate.		√
:PROTection	Path to configure voltage compliance:		√
[:LEVel] <n>	Specify voltage limit for I-Source: (-63 to 63).	21	√
[:LEVel]?	Query voltage compliance limit		√
:TRIPped?	In voltage compliance?: 1 (yes), 0 (no).		√
:RESistance	Path to configure resistance:		√
:MODE <name>	Select ohms mode (MANual or AUTO).	AUTO	
:MODE?	Query ohms mode.		
:OCOMpensated <b>	Enable or disable offset-compensated ohms.	OFF	√
:OCOMpensated?	Query state of offset-compensated ohms.		√
:RANGe	Configure measurement range:		√
[:UPPer] <n>|UP|DOWN	Select range (0 to 2.1e7).	2.1e5	√
[:UPPer]?	Query range.		√
:AUTO <b>	Enable or disable auto range.	ON	√
:AUTO?	Query auto range.		√
:NPLCycles <n>	Specify integration rate (in line cycles): 0.01 to 10.	1.0	√
:NPLCycles?	Query integration rate.		√
:AVERage	Path to configure and control digital filter:		√
:TCONtrol <name>	Specify filter type (MOVing or REPeat).	REPeat	√
:TCONtrol?	Query filter type.		√
:COUNt <n>	Specify filter count (1 to 100).	10	√
:COUNt?	Query filter count.		√
[:STATe] <b>	Enable or disable filter.	OFF	√
[:STATe]?	Query state of filter.		√

Table 5-8
SOURce command summary

Command	Description	Default parameter	SCPI
:SOURce[1]	Path to control sourcing:		√
:CLEar	Path to clear source:		
[:IMMediate]	Turn selected source off		
:AUTO <b>	Enable or disable auto clear for source.		
:AUTO?	Query state of auto clear.	OFF	
:FUNCtion	Source selection:		√
[:MODE] <name>	Select source mode (VOLTage, CURRent, or MEMory).	VOLTage	√
[:MODE]?	Query source selection.		√
:DELay <n>	Specify settling time (in sec) .001 to 999.9999.	0.001	
:AUTO <b>	Enable or disable auto settling time.	ON	
:AUTO?	Query state of auto settling time.		
:DELay?	Query source settling time.		
:CURRent	Path to configure I-Source:		√
:MODE <n>	Select I-Source mode (FIXed, SWEep, or LIST).	FIXed	√
:MODE?	Query I-Source mode.		√
:RANGe <n>|UP|DOWN|	Select fixed I-Source range (-3.15 to 3.15).	1.05e-4	√
:AUTO <b>	Enable or disable autoranging.	ON	√
:AUTO?	Query state of autoranging.		√
:RANGe?	Query I-Source range setting.		√
[:LEVel]	Set I-Source level (in amps):		√
[:IMMediate]	Set level immediately:		√
[:AMPLitude] <n>	Specify current level (-3.15 to 3.15).	0	√
[:AMPLitude]?	Query current level.		√
:TRIGgered	Set level when triggered:		√
[:AMPLitude] <n>	Specify current level (-3.15 to 3.15).	0	√
[:AMPLitude]?	Query current level.		√
:STARt <n>	Specify start level for I-sweep (-3.15 to 3.15).	0	√
:STARt?	Query start level for current sweep.		√
:STOP <n>	Specify stop level for I-sweep (-3.15 to 3.15).	0	√
:STOP?	Query stop level for current sweep.		√
:STEP <n>	Specify step value for I-sweep (-3.15 to 3.15).	0	
:STEP?	Query step value for voltage sweep.		
:SPAN <n>	Specify span (-3.15 to 3.15).	0	√
:SPAN?	Query span?		√
:CENTer <n>	Specify center point (-3.15 to 3.15).	0	√
:CENTer?	Query center point?		√

Table 5-8 (cont.)
SOURce command summary

Command	Description	Default parameter	SCPI
:SOURce[1]			
:VOLTage	Path to configure V-Source:		√
:MODE <n>	Select V-Source mode (FIXed, SWEep, or LIST).	FIXed	√
:MODE?	Query V-Source mode.		√
:RANGe <n>|UP|DOWN|	Select fixed V-Source range (0 to 63).	21	√
:AUTO <b>	Enable or disable autoranging.	ON	√
:AUTO?	Query state of autoranging.		√
:RANGe?	Query V-Source range setting.		√
[:LEVel]	Set V-Source level (in volts):		√
[:IMMediate]	Set specified level immediately:		√
[:AMPLitude] <n>	Specify voltage level (-63 to 63).	0	√
[:AMPLitude]?	Query voltage level.		√
:TRIGgered	Set specified level when triggered:		√
[:AMPLitude] <n>	Specify voltage level (-63 to 63).	0	√
[:AMPLitude]?	Query voltage level.		√
:PROTection	Path to limit output voltage:		√
[:LEVel] <NRf>	Specify voltage limit level (-63 to 63).	(Note)	√
[:LEVel]?	Query voltage limit.		√
:TRIPped?	Voltage limit detected: 1 (yes), 0 (no).		√
:STARt <n>	Specify start level for V-sweep (-63 to 63).	0	√
:STARt?	Query start level for voltage sweep.		√
:STOP <n>	Specify stop level for V-sweep (-63 to 63).	0	√
:STOP?	Query stop level for voltage sweep.		√
:STEP <n>	Specify step value for V-sweep (-63 to 63).	0	
:STEP?	Query step value for voltage sweep.		
:SPAN <n>	Specify span (-63 to 63).	0	√
:SPAN?	Query span.		√
:CENTer <n>	Specify center point (-63 to 63).	0	√
:CENTer?	Query center point.		√
:SWEep	Configure SWEep source mode:		√
:SPACing <name>	Select sweep spacing type (LINear or LOGarithmic).	LINear	√
:SPACing?	Query sweep spacing.		√
:POINts <n>	Specify number of sweep points (2 to 2500).	2500	√
:POINts?	Query number of points in sweep.		√
:DIRection <name>	Sweep from start to stop (UP) or from stop to start (DOWN).	UP	√
:DIRection?	Query sweep direction.		√
:RANGing <name>	Select source ranging mode (BEST, AUTO, or FIXed).	BEST	
:RANGing?	Query source ranging mode.		

Note: SYSTem:PRESet default is 36. *RST default is 63.

Table 5-8 (cont.)
SOURce command summary

Command	Description	Default parameter	SCPI
:SOURce[1]			
:LIST	Configure LIST source mode:		√
:CURRent <NRf>	Create list of I-Source values (-3.15 to 3.15).		√
:APPend <NRf>	Add I-Source values to end of list.		
:POINts?	Query number of source values in list.		√
:CURRent?	Query I-Source list.		
:VOLTage <NRf>	Create list of V-Source values (-63 to 63).		√
:APPend <NRf>	Add V-Source values to end of list.		
:POINts?	Query number of source values in list.		√
:VOLTage?	Query V-Source list.		
:MEMory	Configure Source Memory Sweep:		
:SAVE <n>	Save settings at memory location (1 to 100).		
:RECall <n>	Recall settings from memory (1 to 100).	1	
:POINts <n>	Specify number of sweep points (1 to 100).		
:POINts?	Query number of sweep points.		
:STARt <NRf>	Specify start location for Source Memory Sweep (1 to 100).	1	
:STARt?	Query start location.		
:SOURce2	Path to control digital output lines:		
:TTL			
[:LEVel] <NRf>	Specify digital output pattern (0 to 15).	15	
[:LEVel]?	Query output pattern.		
:CLEar	Clear digital output:		
[:IMMediate]	Restore (clear) to :TTL output pattern.		
:AUTO <b>	Enable or disable auto-clear.	ON	
:AUTO?	Query state of auto-clear.		
:DELay <n>	Specify pulse-width of pass/fail pattern (0.0000 to 60 sec).	0.00001	
:DELay?	Query delay.		

Table 5-9
STATus command summary

Command	Description	Default parameter	SCPI
:STATus		(Note 1)	√
:MEASurement	Control measurement event registers:		
[:EVENt]?	Read the event register (see Note 6).	(Note 2)	√
:ENABle <NDN> or <NRf>	Program the enable register.	(Note 3)	√
:ENABle?	Read the enable register (see Note 6).		
:CONDition?	Read the condition register (see Note 6).		√
:OPERation	Control operation status registers:		√
[:EVENt]?	Read the event register (see Note 6).	(Note 2)	√
:ENABle <NDN> or <NRf>	Program the enable register.	(Note 3)	√
:ENABle?	Read the enable register (see Note 6).		√
:CONDition?	Read the condition register (see Note 6).		√
:QUEStionable	Control questionable status registers:		√
[:EVENt]?	Read the event register (see Note 6).	(Note 2)	√
:ENABle <NDN> or <NRf>	Program the enable register.	(Note 3)	√
:ENABle?	Read the enable register (see Note 6).		√
:CONDition?	Read the condition register (see Note 6).		√
:PRESet	Return status registers to default states.		√
:QUEue	Path to access error queue:		
[:NEXT]?	Read the most recent error message.	(Note 4)	√
:ENABle <list>	Specify error and status messages for error queue.	(Note 5)	√
:ENABle?	Read the enabled messages.		√
:DISable <list>	Specify messages not to be placed in error queue.	(Note 5)	
:DISable?	Read the disabled messages.		
:CLEar	Clears all messages from error queue.		

Notes:

1. Commands in this subsystem are not affected by *RST and :SYSTem:PREset. The effects of cycling power, *CLS and :STATus:PRESet, are explained by the following notes.
2. Event Registers — Power-up and *CLS clears all bits.:STATus:PRESet has no effect.
3. Enable Registers — Power-up and :STATus:PRESet clears all bits. *CLS has no effect. Accept the SCPI 1995.0 mandated (non-decimal numeric) format (#H, #Q, or #B).
4. Error Queue — Power-up and *CLS clears all bits of the registers.
5. Error Queue Messages — Power-up clears list of messages. *CLS and :STATus:PRESet have no effect.
6. Register Query Commands — The format for the response messages (ASCII, hexadecimal, octal, or binary) depends on which data format is presently selected (see: FORMat:SREGister command).

Table 5-10
SYSTem command summary

Command	Description	Default parameter	SCPI
:SYSTem			
:PRESet	Return to :SYSTem:PRESet defaults.		√
:POSetup <name>	Select power-on setup (RST, PRESet, or SAV 0-4).		
:POSetup?	Query power-on setup.		
:VERSion?	Query revision level of SCPI.		√
:ERRor	Path to read messages in error queue (see Note 1):		
[:NEXT]?	Return and clear oldest error (code and message).		√
:ALL?	Return and clear all errors (codes and messages).		√
:COUNt?	Return the number of errors.		√
:CODE	Path to return error code numbers only:		√
:[NEXT]?	Return and clear oldest error (code only).		√
ALL?	Return and clear all errors (codes only).		√
:CLEar	Clears messages from error queue.		
:RSENse <b>	Enable or disable remote sensing.	OFF	
:RSENse?	Query state of remote sensing.		
:KEY <n>	Simulate key-press (0 to 31). See Figure 5-9.		√
:KEY?	Query the last "pressed" key.		√
:GUARd <name>	Select guard type; OHMS or CABLe.	CABLe	
:GUARd?	Query guard type.		
:FCONtrol <name>	Select fan speed for output off: ALWays (range dependent) or OUTPut (low speed).	OUTPut	
:BEEPer	Control beeper:		
[:IMMediate] <freq, time>	Beep at specified frequency (65 to 2e6 Hz) for specified time period (0 to 7.9 seconds)		
:STATe <b>	Enable or disable beeper.	ON	√
:STATe?	Query state of beeper.		√
:AZERo	Control auto-zero:		
[:STATe] <b>	Enable or disable auto-zero.	ON	√
[:STATe]?	Query state of auto-zero.		√
:FRSWitch <name>	Select in/out terminals; FRONt or REAR (see Note 2).	FRONt	
:FRSWitch?	Query in/out terminals.		
:LFRequency <freq>	Select line frequency; 50 or 60 (Hz):		
:AUTO <b>	Enable or disable auto frequency.	(see Note 3)	
:AUTO?	Query state of auto frequency.		
LFRequency?	Query line frequency.		

Table 5-10 (cont.)
SYSTem command summary

Command	Description	Default parameter	SCPI
:TIME	Timestamp:		
:RESet	Reset timestamp to zero seconds.		
:MEMory	Initalize memory:		√
:INITialize	Initialize battery backed RAM.		√
:LOCal	Take unit out of remote (RS-232 only).		
:REMote	Put unit in remote (RS-232 only).		
:RWLock <b>	Enable or disable local lockout (RS-232 only).		

NOTES:
1. Clearing Error Queue - Power-up and *CLS clears the error queue. *RST, :SYSTem:PRESet, and :STATus:PRESet have no effect.
2. For SCPI compatibility, use the :ROUTe:TERMinals command to select in/out terminals.
3. The auto line frequency setting is not affected by *RST and :SYSTem:PRESet.

Table 5-11
TRACe command summary

Command	Description	Default parameter	SCPI
:TRACe:DATA	Use :TRACe or :DATA as root command:	(see note)	√
:DATA?	Read the contents of the buffer (data store).		√
:CLEar	Clear readings from buffer.		
:FREE?	Query bytes available and bytes in use.		√
:POINts <NRf>	Specify size of buffer; 1 to 2500.		√
:ACTual?	Queries number of readings stored in the buffer.		
:POINts?	Query buffer size.		√
:FEED <name>	Select source of readings; SENSe[1], CALCulate[1], or CALCulate2.		√
:CONTrol <name>	Specify buffer control mode; NEVER or NEXT.		√
:CONTrol?	Query buffer control mode.		√
:TSTamp	Path to set timestamp format:		
:FORMat <name>	Select format; ABSolute or DELTa.		
:FORMat?	Query timestamp format.		

NOTE: :SYSTem:PRESet and *RST have no effect on the commands in this subsystem.

Table 5-12
Trigger command summary

Command	Description	Default parameter	SCPI
:INITiate[:IMMediate]	Initiate source-measure cycle(s).		√
:ABORt	Reset trigger system. Goes to idle state.		√
:ARM	Path to program Arm Layer:		√
[:SEQuence[1]]			√
[:LAYer[1]]			√
:COUNt <n>	Specify arm count; 1 to 2500.	1	√
:COUNt?	Query arm count.		√
:SOURce <name>	Specify control source (IMMediate, TIMer, MANual, BUS, TLINk or STESt).	IMMediate	√
:SOURce?	Query control source.		√
:TIMer <n>	Set timer interval in seconds (0 to 99999.99).	0.1	√
:TIMer?	Query timer interval.		√
[:TCONfigure]			√
:DIRection <name>	Enable (SOURce) or disable (ACCeptor) bypass.	ACCeptor	√
:DIRection?	Query state of bypass.		√
[:ASYNchronous]	Configure output triggers:		√
:ILINe <n>	Select input trigger line (1, 2, 3, or 4).	1	
:ILINe?	Query input trigger line.		
:OLINe <n>	Select output trigger line (1, 2, 3, or 4).	2	
:OLINe?	Query output trigger line.		
:OUTPut <name>	Output TRIGger or not (NONE).	NONE	
:OUTPut?	Query arm output trigger status.		
:TRIGger	Path to program Trigger Layer:		√
[:SEQuence[1]]			√
:COUNt <n>	Specify trigger count (1 to 2500).	1	√
:COUNt?	Query trigger count.		√
:DELay <n>	Specify trigger delay (0 to 999.9999 (sec)).	0	√
:DELay?	Query source delay.		√
:SOURce <name>	Specify control source (IMMediate or TLINk).	IMMediate	√
:SOURce?	Query control source.		√
[:TCONfigure]			√
:DIRection <name>	Enable (SOURce) or disable (ACCeptor) bypass.		√
:DIRection	Query state of bypass.		√
[:ASYNchronous]	Configure output triggers:		√
:ILINe <n>	Select input trigger line (1, 2, 3, or 4).	1	
:ILINe?	Query input trigger line.		
:OLINe <n>	Select output trigger line (1, 2, 3, or 4).	2	
:OLINe?	Query output trigger line.		
:OUTPUT <event list>	Output trigger after SOURce, DELay, SENSe or not (NONE) at all.	NONE	
:OUTPut?	Query when output trigger is going to occur.		

Calculate subsystems

There are three Calculate Subsystems. The CALC1 Subsystem is used for math expressions, CALC2 is used for limit tests, and CALC3 provides statistical data on readings stored in the buffer. The commands in these subsystems are summarized in Table 5-2.

CALCulate[1]

Configure and control math expressions

NOTE *Percent deviation (%DEV) is included in the catalog as a built-in math expression but is only available from the front panel. However, percent deviation can be added as a user-defined math expression for remote operation. A program example shows how to create the percent deviation math expression (see "Program examples").*

Select (create) math expression name

:CATalog?

:CALCulate[1]:MATH[:EXPression]:CATalog? Query list of expression names

Description This query command is used to list the math expression names. This list includes the built-in expression names as well as the names of expressions defined by the user. The names for the built-in expressions are as follows:

"POWER", "OFFCOMPOHM", "VOLTCOEF", "VARALPHA", "%DEV"

Thus, the :CATalog? command will return the above names as well as the names of any user-defined expressions. See :NAME to assign names to user-defined expressions.

:NAME <name>

:CALCulate[1]:MATH[:EXPression]:NAME <name> Select math expression

Parameters

<name> =	"POWER"	Instantaneous power equation
	"OFFCOMPOHM"	Offset compensated ohms equation
	"VOLTCOEF"	Resistor voltage coefficient equation
	"VARALPHA"	Varistor alpha equation
	"user-name"	Assigned name for user-defined expression where the user name is made up of ASCII characters (up to 10).

Query :NAME? Query selected math expression

Description This command can be used to select a math expression that already exists (built-in or user-defined). Math expression names that already exist can be listed using the :CATalog? command. The actual math expression can be read using the :MATH? command. The built-in math expressions (except POWER) require a two-point sweep in order to perform the calculation. The "Program fragments " show how to configure the SourceMeter for these math expressions.

When you want to create a new user-defined math expression, perform the following steps in order:

1. Assign a name to the expression (using up to 10 ASCII characters) using this command.
2. If desired, assign units to the calculation result (see :UNITs). Units is stored for the calculation.
3. Define the expression using the :DEFine or EXPRession command. The new expression is the one that will be presently selected.

Math expression errors:

+801 "Insufficient vector data" — Returned to idle before acquiring enough data to fully populate the vector. A CALC1 result is not built.

+804 "Expression list full" — Attempted to create a new expression name when the list (catalog) is full. The maximum number of user-defined expression names is five.

+805 "Undefined expression exists" — Attempted to create a new expression name while a previous expression name remains undefined. Remember, after creating a name, you have to define the expression.

+806 "Expression not found" — Attempted to delete a named math expression that cannot be found.

+807 "Definition not allowed" — Attempted to define an expression that has not been previously named.

+808 "Expression cannot be deleted" — Attempted to delete one of the built-in math expressions (see :DELete).

+809 "Source memory location revised" — Occurs when a :SOURce:MEMory sweep location references an expression that no longer exists.

+811 "Not an operator or number" — Defined a null math expression by not using a valid operator or number.

+812 "Mismatched parenthesis" — Number of open parentheses must be the same as the number of closed parentheses. For example, CALC1:MATH:EXPR (2*sin(VOLT) generates this error.

+813 "Not a number of data handle" — An invalid floating point number or symbol other than VOLT, CURR, RES, or TIME appears in the math expression.

+814 "Mismatched brackets" — Improper use of brackets for vectored math expression indices. For example, CALC1:MATH:EXPR (VOLT[0*CURR[0]) generates this error.

+815 "Too many parenthesis" — Too many closed parentheses were detected. For example, CALC1:MATH:EXPR (In(VOLT))) generates this error.

+816 "Entire expression not parsed" — Occurs when the input expression does not produce a function for the SourceMeter to calculate.

+817 "Unknown token" — Attempted to define an expression using an invalid function name.

+818 "Error parsing mantissa" — Occurs when a floating point number has an invalid mantissa.

+819 "Error parsing exponent" — Occurs when a floating point number has an invalid exponent.

+820 "Error parsing value" — Occurs when an invalid floating point number is entered.

+821 "Invalid data handle index" — An invalid array index value was assigned to a vectored expression. Array indices start at 0 and can be as high as 2499.

Notes:

- Up to five user-defined math expressions can be created.
- A selected math expression can only be performed if CALC1 is enabled (see :STATe).
- When the math expression is vectored, the math result will not be generated until all source-measure operations for the vector array are performed.
- Initializing memory (:SYSTem:MEMory:INITialize) deletes all user-defined math expressions and selects the POWER expression.

Program Examples

OFFCOMPOHM, VOLTCOEF, and VARALPHA require two source-measure sweep points in order to perform the math expressions. Shown below are code fragments that will properly configure the SourceMeter to perform the built-in math expressions:

Power:

```
*RST
:SENS:FUNC:OFF:ALL
:SENS:FUNC                  "VOLT","CURR"
:CALC:MATH:EXPR:NAME        "POWER"
:CALC:STAT                  ON
:OUTPUT                     ON
:INIT
:CALC:DATA?
```

Offset compensated ohms:

```
*RST
:SENS:FUNC:OFF:ALL
:SENS:FUNC                  "VOLT","CURR"
:SOUR:FUNC                  VOLT or CURR
if :SOUR:FUNC VOLT then     :SOUR:VOLT:STAR <n>;STOP <n>
                            ;MODE SWE
if :SOUR:FUNC CURR then     :SOUR:CURR:STAR <n>;STOP <n>
                            ;MODE SWE
:SOUR:SWE:POIN              2
:TRIG:COUN                  2
:CALC:MATH:EXPR:NAME        "OFFCOMPOHM"
:CALC:STAT                  ON
:OUTPUT                     ON
:INIT
:CALC:DATA?
```

Resistor voltage coefficient

```
*RST
:SENS:FUNC:ON:ALL
:SENS:RES:MODE                  MAN
:SOUR:FUNC                      VOLT or CURR
if :SOUR:FUNC VOLT then         :SOUR:VOLT:STAR <n>;STOP <n>
                                ;MODE SWE
if :SOUR:FUNC CURR then         :SOUR:CURR:STAR <n>;STOP <n>
                                ;MODE SWE
:SOUR:SWE:POIN                  2
:TRIG:COUN                      2
:CALC:MATH:EXPR:NAME            "VOLTCOEF"
:CALC:STAT                      ON
:OUTPUT                         ON
:INIT
:CALC:DATA?
```

Varistor alpha

```
*RST
:SENS:FUNC:OFF:ALL
:SENS:FUNC:ON                   "VOLT","CURR"
:SOUR:FUNC:MODE                 CURR
:SOUR:CURR:STAR                 <n>;STOP <n>;MODE SWE
:TRIG:COUN                      2
:CALC:MATH:EXPR:NAME            "VARALPHA"
:CALC:STAT                      ON
:OUTPUT                         ON
:INIT
:CALC:DATA?
```

Percent Deviation

NOTE *Percent deviation is not a built-in math expression for remote operation. This program example creates the following percent deviation (PER_DEV) calculation to test 10kΩ resistors. This user-defined math expression is added to the catalog.*

$$PER_DEV = \frac{(RES - 10k\Omega)}{10k\Omega} \times 100$$

where: RES is the actual measured resistance of the DUT.
10kΩ is the reference value.

```
*RST
:SENS:FUNC:OFF:ALL
:SENS:FUNC:ON or "RES"
:CALC:MATH:UNIT "%"
:CALC:MATH:EXPR:NAME "PER_DEV"
:CALC:MATH:EXPR ((RES - 10e3) / 10e3) * 100
:CALC:MATH:EXPR:NAME "PER_DEV"
:CALC:STAT ON
:OUTPUT ON
:INIT
:CALC:DATA?
```

NOTE *Parameter <n> referenced in the :SOUR:VOLT and :SOUR:CURR commands above represent the actual numbers that the user would program. All other commands should be entered as shown.*

:DELete[:SELected] <name>

:CALCulate[1]:MATH[:EXPRession]:DELete[:SELected] <name> Delete user-defined math expression

Parameters <name> = "user-name" Name of user-defined math expression

Description This command is used to remove (delete) the specified user-defined math expression from the catalog. Once removed, that math expression can no longer be selected. You can use the :CATalog? command to verify that the math expression is gone.

For example, if you wish to delete a user-defined math expression that is named "math1", you would send the following command:

:DELete "math1"

You cannot delete built-in math expressions. This will result in error +808 "Expression cannot be deleted".

:DELete:ALL

:CALCulate[1]:MATH[:EXPRession]:DELete:ALL Delete all user-defined math expression

Description This action command will remove (delete) all user-defined math expressions from the catalog. Built-in math expressions are not affected.

Assign unit suffix

:UNITs <name>

:CALCulate[1]:MATH:UNITs <name> Specify units for user-defined calculation

Parameters <name> = Three ASCII characters enclosed in single or double quotes

Query :UNITs? Query units for user-defined calculation

Description This command is used to specify the units suffix name for a user-defined math calculation. Use three ASCII characters for the units suffix name. If using fewer than three characters, add spaces to the right of the units name in the string. For example, if the units name is "Z", send it as follows:

:calc:math:unit "Z "

The units name can also be enclosed in single quotes as follows:

:calc:math:unit 'Z '

NOTE *The units must be set before defining a user math expression so they can be saved with the user-defined expression.*

Define math expression

[:EXPRession] <form> or [:DEFine] <form>

:CALCulate[1]:MATH[:EXPRession] <form> Define math formula
:CALCulate[1]:MATH[:EXPRession][:DEFine] <form> Define math formula

Parameters <form> = mathematical formula using instrument readings, numbers and standard math operator symbols. See Description for details.

Query :MATH? Query user-defined math expression

Description Use either of these two commands to define a math formula using measure and source readings, numeric constants, and standard math operator symbols. After the math expression is defined, it will be assigned to the name that was created using the :NAME command and will become the selected math expression. See :NAME for more details.

Valid parameter names for measure and source readings include:

VOLTage	Use V-Measure or V-Source reading
CURRent	Use I-Measure or I-Source reading
RESistance	Use ohms reading
TIME	Use timestamp reading

Valid math operators and their operations are listed as follows:

+	Add
-	Subtract
*	Multiply
/	Divide
^	Exponent
log	Logarithmic, base 10
ln	Natural log
sin	Sine
cos	Cosine
tan	Tangent
exp	e^x

NOTE *The log and ln operations are performed on the absolute value of the specified number. For example, log (100) = 2 and log (-100) = 2.*

Expressions are evaluated according to the following precedence rules:

1. Enclosed by parentheses
2. Unary operators (+ and -)
3. ^ (exponentiation)
4. * (multiplication) and / (division)
5. + (addition) and - (subtraction)
6. Left to right.

The readings used for the calculation depend on how the SourceMeter is configured. If configured to Source V Measure I, the voltage reading for the calculation will be the source value, and the current reading will be the current measurement. Conversely, if configured to Source I Measure V, the current reading will be the source value, and the voltage reading will be the voltage measurement.

Measure readings take priority over source readings. Thus, if configured to Source V Measure V, the voltage reading for the calculation will be the voltage measurement (not the programmed V-Source value). Conversely, if configured to Source I Measure I, the current reading for the calculation will the current measurement.

The result of a calculation using a reading that is not sourced or measured will be the invalid NAN (not a number) value of +9.91e37. For example, using a current reading in a calculation for Source V Measure V will cause a NAN result.

Example using Source I Measure V configuration:

:calc:math (volt * curr)	Calculate power using voltage measurement and I-Source value.

After a calculation is configured and enabled (see :STATe), the results are displayed when source-measure operations are performed. Use the :data? command to send the results to the computer.

Vectored math

By incorporating vectors, you select which readings to use for the math calculation. After all programmed source-measure operations are completed, the math calculation(s) are performed using readings indicated by the specified vectors.

Vector numbers are enclosed in brackets ([]), and start at 0. Thus, vector 0 is the first reading in the array, vector 1 is the second reading in the array, and so on. The largest vector number in the expression defines the vector array size.

For example, assume the SourceMeter is programmed to perform 10 source-measure operations, and the following vectored math calculation is used:

(volt[3] - volt[9])

The above expression defines a vector array that is made up of 10 readings. Since the SourceMeter is programmed to perform 10 source-measure operations, the calculation will yield one result every 10 SDM cycles. The fourth voltage reading (vector 3) and the 10th voltage reading (vector 9) are used for the calculation.

Now assume that the SourceMeter is configured to perform 20 source-measure operations. Since the vector size is still 10, two 10-reading arrays will be created. The calculation will now yield two results, one for each array.

The first result, as before, is based on the fourth and 10th readings of the first array. The second result is based on the 14th and 20th readings. These are the fourth (vector 3) and 10th (vector 9) readings of the second array.

Note that you need complete vector arrays to acquire valid calculation results. If, in the preceding example, the SourceMeter is changed to perform 25 source-measure operations, then the third array will be incomplete (first array is 10 readings, second array is 10 readings, third array is only 5 readings). After the SourceMeter goes back into idle, the "Insufficient vector data" error message will be displayed, and the third result will be NAN (+9.91e37).

To avoid incomplete vector arrays, make sure the programmed number of source-measure operations (arm count × trigger count) is a multiple of the vector array size. In the preceding example, vector array size is 10. Thus, in order to avoid "Insufficient vector data" errors, the programmed number of source-measure operations has to be a multiple of 10 (10, 20, 30, 40 and so on).

The following vector math expression to calculate offset compensated ohms demonstrates proper syntax:

:calc:math ((volt[1] - volt[0]) / (curr[1] - curr[0]))

Notes:

1. Use nested parentheses to force math operations that are imbedded in the calculation (see example in "Vector Math").
2. A calculation expression can be up to 256 characters in length, including parentheses and white spaces.
3. When using the filter, the measured readings used in the calculation are filtered - NOT the result of the calculation.
4. For vector math, it is recommended that only the REPEAT filter be used. For the repeat filter, the calculations use only the filtered readings of the vector points. If you instead use the MOVING filter, each vector point will reflect the filtered average of all the previous readings in the vector array.
5. The data format (ASCII or binary) for calculation results is selected using the :FORMat:DATA? command (see FORMat Subsystem). The *RST and :SYSTem:PRESet default is ASCII.
6. When bracktets ([]) are left out of an expression, it is assumed that it is referencing the first vector point in the array (i.e., VOLT is the same as VOLT[0]).

Enable and read math expression result

:STATe <b>

:CALCulate[1]:STATe <b> Control CALC1

Parameters <b> = 0 or OFF Disable CALC1 calculation
1 or ON Enable CALC1 calculation

Query :STATe? Query state (on or off) of CALC1

Description This command is used to enable or disable the CALC1 calculation. When enabled, the selected math expression will be performed when the SourceMeter is triggered to perform the programmed source-measure operations.

After the SourceMeter returns to idle, you can read the result of the selected math expression using the :CALC1:DATA? command (see next command).

When disabled, the :CALC1:DATA? command will return the NAN (not a number) value of +9.91e37.

:DATA?

:CALCulate[1]:DATA? Read CALC1 result

Description This query command is used to read the result of the CALC1 calculation. The largest valid calculation result can be ±9.9e37, which (defined by SCPI) is infinity.

For scalar math (non-vectored math), this command is used to return calculation results for all the programmed source-measure points. For example, if 20 source-measure operations were performed, this command will return 20 calculation results.

For vector math, this command will only return the calculation results for the specified vector points.

An invalid NAN (not a number) result of +9.91e37 indicates that one of the following conditions exist:

- Error in the expression.
- The required measurement function is disabled.
- CALC1 is disabled (see :STATe).

NOTE *See "Data Flow" in Appendix D for a detailed explanation on how data flows through the various operation blocks of the SourceMeter. It clarifies the type of readings that are acquired by the various commands to read data.*

CALCulate2

Configure and control limit tests

The following commands are used to configure and control the three limit tests for DUT. When used with a handler to provide binning operations, communication between the SourceMeter and the handler is provided via the Digital I/O port. Many control aspects of the digital output lines are performed from the SOURce2 Subsystem. These control aspects include setting and clearing the digital output lines, and setting pulse width. See "SOURce2 subsystem" for details.

Select input path

:FEED <name>

:CALCulate2:FEED <name> — Select input path for limit tests

Parameters

<name> =	CALCulate[1]	Use result of CALC1
	VOLTage	Use measured voltage reading
	CURRent	Use measured current reading
	RESistance	Use measured resistance reading

Query :FEED? Query input path for limit tests

Description This command is used to select the input path for the limit tests. With CALCulate[1] selected, the specified limits will be compared to the result of CALC1. With VOLTage selected, limits will be compared to the voltage measurement. With CURRent or RESistance selected, limits will be compared with the respective current or resistance measurement.

Null feed reading

:OFFSet <n>

:CALCulate2:NULL:OFFSet <n> — Specify null offset (REL) for feed

Parameters

<n> =	-9.999999e20 to 9.999999e20	Specify null offset value

Query :OFFSet? Query null offset value

Description This command lets you establish a null offset (REL) for the selected feed. When Null Offset is enabled (see :NULL:STATe), the result is the algebraic difference between the feed reading and the offset value:

CALC2 reading = feed reading - null offset

:STATe <b>

:CALCulate2:NULL:STATe <b> Control null offset

Parameters <b> = 1 or ON Enable null offset
0 or OFF Disable null offset

Query :STATe? Query state of null offset

Description This command is used to enable or disable null offset. When enabled, the CALC2 reading will include the null offset value (see :OFFSet). When disabled, CALC2 will not include the null offset.

Read CALC2

:DATA?

:CALCulate2:DATA? Read CALC2

Description This command is used to acquire the readings used for the CALC2 limit tests. Note that if null offset is enabled (see Null Feed Reading), then the CALC2 readings will include the null offset value.

At least one of the limit tests have to be enabled to a acquire limit test readings (see "Configure and control limit tests; :STATe").

NOTE *See "Data Flow" in Appendix D for a detailed explanation on how data flows through the various operation blocks of the SourceMeter. It clarifies the type of readings that are acquired by the various commands to read data.*

Configure and control limit tests

:COMPliance:FAIL <name>

:CALCulate2:LIMit[1]:COMPliance:FAIL <name>

Parameters <name> = IN Fail Limit 1 test when unit goes into compliance
OUT Fail Limit 1 test when unit comes out of compliance

Query :FAIL? Query when Limit 1 test failure occurs

Description This command is used to specify the condition that will cause Limit 1 test to fail. With IN specified, the test will fail when the SourceMeter goes into compliance. With OUT specified, the test will fail when the SourceMeter comes out of compliance.

[:DATA] <n>

:CALCulate2:LIMit2:LOWer[:DATA] <n> Specify lower LIMIT 2
:CALCulate2:LIMit2:UPPer[:DATA] <n> Specify upper LIMIT 2
:CALCulate2:LIMit3:LOWer[:DATA] <n> Specify lower LIMIT 3
:CALCulate2:LIMit3:UPPer[:DATA] <n> Specify upper LIMIT 3

Parameters

<n> = -9.999999e20 to 9.999999e20		Specify limit value
	DEFault	Set specified lower limit to -1 Set specified upper limit to 1
	MINimum	Set specified limit to -9.999999e20
	MAXimum	Set specified limit to +9.999999e20

Query

:UPPer?	Query specified upper limit
:UPPer? DEFault	Query *RST default upper limit
:UPPer? MINimum	Query lowest allowable upper limit
:UPPer? MAXimum	Query largest allowable upper limit
:LOWer?	Query specified lower limit
:LOWer? DEFault	Query *RST default lower limit
:LOWer? MINimum	Query lowest allowable lower limit
:LOWer? MAXimum	Query largest allowable lower limit

Description These commands are used to set the upper and lower limits for LIMIT 2 and LIMIT 3 tests. The actual limit depends on which measurement function is currently selected. For example, a limit value of 1μ is 1μA for the amps function and 1μV for the volts function. A limit value is not range sensitive. A limit of 2 for volts is 2V on all measurement ranges.

:SOURce2 <NRf>

:CALCulate2:LIMit[1]:COMPliance:SOURce2 <NRf> Specify pattern; LIMIT 1 failure
:CALCulate2:LIMit2:LOWer:SOURce2 <NRf> Specify pattern; lower LIMIT 2 failure
:CALCulate2:LIMit2:UPPer:SOURce2 <NRf> Specify pattern; upper LIMIT2 failure
:CALCulate2:LIMit3:LOWer:SOURce2 <NRf> Specify pattern; lower LIMIT3 failure
:CALCulate2:LIMit3:UPPer:SOURce2 <NRf> Specify pattern; upper LIMIT3 failure

Parameters <NRf> = 0 to 15 Specify digital pattern for output port

Query :SOURce2? Query source value for specified limit

Description These commands are used to define the 4-bit digital output "fail" patterns (0 to 15) for the specified tests.

Tests are performed in the following order:

1. Limit Test 1
2. Limit Test 2
   A. Lower Limit 2
   B. Upper Limit 2
3. Limit Test 3
   C. Lower Limit 3
   D. Upper Limit 3

The first failure in the test sequence determines the bit pattern for the digital output port. Subsequent failures in the test sequence will not change the defined digital output pattern.

Use the following table to determine the parameter value for the desired digital output pattern:

OUT 4	OUT 3	OUT 2	OUT 1	Value
L	L	L	L	0
L	L	L	H	1
L	L	H	L	2
L	L	H	H	3
L	H	L	L	4
L	H	L	H	5
L	H	H	L	6
L	H	H	H	7
H	L	L	L	8
H	L	L	H	9
H	L	H	L	10
H	L	H	H	11
H	H	L	L	12
H	H	L	H	13
H	H	H	L	14
H	H	H	H	15

L = Low (Gnd)
H = High (>+3V)

The SourceMeter can be configured to place the defined "fail" bit pattern on the digital output immediately when a "fail" condition occurs, or it can wait until all testing on a device package is completed (operation leaves trigger layer). See "Composite Testing; :BCONtrol" for details.

:STATe <b>

:CALCulate2:LIMit[1]:STATe <b> — Control LIMIT 1 test
:CALCulate2:LIMit2:STATe <b> — Control LIMIT 2 test
:CALCulate2:LIMit3:STATe <b> — Control LIMIT 3 test

Parameters

<b> = 1 or ON — Enable specified limit test
0 or OFF — Disable specified limit test

Query

:STATe? — Query state of specified limit test

Description

These commands are used to enable or disable LIMIT 1, LIMIT 2 and LIMIT 3 tests. Any limit test not enabled is simply not performed.

When a limit test is enabled, the Digital I/O port comes under control of limit tests. That is, the result of the testing process updates the output pattern on the I/O port.

:FAIL?

:CALCulate2:LIMit[1]:FAIL?	Read LIMIT 1 test result
:CALCulate2:LIMit2:FAIL?	Read LIMIT 2 test result
:CALCulate2:LIMit3:FAIL?	Read LIMIT 3 test result

Description These commands are used to read the results of LIMIT 1, LIMIT 2 and LIMIT 3 tests:

0 = Limit test passed
1 = Limit test failed

The response message (0 or 1) only tells you if a limit test has passed or failed. For Limit 2 and Limit 3, it does not tell you which limit (upper or lower) has failed. To determine which limit has failed, you will have to read the Measurement Event Register (see "Status Subsystem").

Reading the results of a limit test does not clear the fail indication of the test. A failure can be cleared by using a :CLEar command.

PASS:SOURce2 <NRf>

:CALCulate2:CLIMits:PASS:SOURce2 <NRf> Specify "pass" pattern

Parameters <NRf> = 0 to 15 Specify digital pattern for output port

Query :SOURce2? Query programmed source value

Description This command is used to define the 4-bit output pattern for the Digital I/O Port when there are no failures. Each output line is assigned a decimal weight. Use the table provided in the "Description" for the :SOURce command to determine the parameter value for the desired digital output pattern.

The SourceMeter can be configured to place the defined "pass" bit pattern on the digital output immediately when the "pass" condition occurs, or it can wait until all testing on a device package is completed (operation leaves trigger layer). See "Composite Testing; :BCONtrol" for details.

PASS:SMLocation <NRf> | NEXT

:CALCulate2:CLIMits:PASS:SMLocation <NRf> | Next Specify "pass" source memory location

Parameters

<NRf> = 1 to 100	Specify memory location point
NEXT	Next memory location point in list (present location + 1)

Query :SMLocation? Query "pass" source memory location

Description While using a Source Memory Sweep when performing limit tests, the sweep can branch to a specified memory location point or proceed to the next memory location in the list.

When a memory location is specified, the sweep will branch to that memory location if the test is successful (PASS condition). If not successful (FAIL condition), the sweep proceeds to the next memory location in the list. With NEXT selected (the default), the sweep proceeds to the next memory location (present location + 1) in the list regardless of the outcome of the test (PASS or FAIL condition).

See "Source Memory Sweep" in Section 2 for more information.

:BCONtrol <name>

:CALCulate2:CLIMits:BCONtrol <name> — Control Digital I/O port pass/fail update

Parameters

<name> =	IMMediate	Update output when first failure occurs
	END	Update output after sweep is completed

Query :BCONtrol? Query when digital output will update

Description This command is used to control when the digital output will update to the "pass" or "fail" bit pattern. The "pass" or "fail" bit pattern tells the handler to stop the testing process and place the DUT in the appropriate bin.

With IMMediate selected, the digital output will update immediately to the bit pattern for the first failure in the testing process. If all the tests pass, the output will update to the "pass" bit pattern.

With END selected, the digital output will not update to the "pass" or "fail' bit pattern until the SourceMeter completes the sweep or list operation. This allows multiple test cycles to be performed on DUT. With the use of a scanner card, multi-element devices (i.e. resistor network) can be tested. If, for example, you didn't use END and the first element in the device package passed, the "pass" bit pattern will be output. The testing process will stop and the DUT will be binned. As a consequence, the other elements in the device package are not tested.

Clear test results

[:IMMediate]

:CALCulate2:CLIMits:CLEar[:IMMediate] — Clears test results and resets Digital I/O Port

Description This command clears the test results (pass or fail) of the limit tests and resets the output lines of the Digital I/O port back to the :SOURce2:TTL settings (see "SOURce2 Subsystem").

:AUTO <b>

:CALCulate2:CLIMits:CLEar:AUTO <b> — Control auto-clear for test results

Parameters

<b> =	1 or ON	Enable auto-clear
	0 or OFF	Disable auto-clear

Query :AUTO? Query state of auto-clear

Description With auto-clear enabled, test results will clear and the output lines of the Digital I/O port will reset when the :INITiate command is sent to start a new test sequence.

When disabled, you must use :IMMediate to perform the clear actions.

CALCulate3

Provides statistical data on buffer readings

Select statistic

:FORMat <name>

:CALCulate3:FORMat <name> Specify CALC3 format

Parameters

<name> =	MEAN	Mean value of readings in buffer
	SDEViation	Standard deviation of readings in buffer
	MAXimum	Largest reading in buffer
	MINimum	Lowest reading in buffer
	PKPK	MAXimum - MINimum

Query :FORMat? Query programmed math format

Description This command is used to select the desired statistic on readings stored in the buffer. See "Data Store" in Section 3 for details on these statistics.

Readings stored in the buffer can be "raw" measured readings, the results of the CALC1 calculation, or CALC2 readings. The :TRACe:FEED command in the :TRACe Subsystem is used to select the type of readings to store.

Acquire statistic

:DATA?

:CALCulate3:DATA? Read CALC3 result

Description This query command is used to perform the selected statistic operation and read the result(s). The result(s) is always returned in ASCII format.

If the buffer is configured to store "raw" measured readings (:TRACe:FEED SENSe1) and multiple functions were measured, the selected statistic operation will be performed on all the measured readings. For example, if voltage and current measurements were stored in the buffer, then the selected statistic operation will be performed on both readings. Statistics for multiple measurement functions are returned in the following order:

voltage statistic, current statistic, resistance statistic.

Statistic operations are not performed on TIME and STATus data elements that are stored in the buffer.

If the buffer is configured to store the result of CALC1 or CALC2 (:TRACe:FEED CALC1 or CALC2), only one result will be returned by this query command.

NOTE *If there is no data in the buffer, the NAN (not a number) value +9.91e37 will be returned.*

If there are a lot of readings stored in the buffer, some statistic operations may take too long and cause a bus time-out error. To avoid this, send the :calc3:data? command and then wait for the MAV (message available) bit in the Status Byte Register to set before addressing the Model 2420 to talk (see "Status structure" in Section 4).

See "Data flow" in Appendix D for a detailed explanation on how data flows through the various operation blocks of the SourceMeter. It clarifies the types of readings that are acquired by the various commands to read data.

:DISPlay subsystem

The display subsystem controls the display of the Model 2420 and is summarized in Table 5-3.

Control display

:DIGits <n>

:DISPlay:DIGits <n> — Set display resolution

Parameters

<n> =	4	3.5 digit resolution
	5	4.5 digit resolution
	6	5.5 digit resolution
	7	6.5 digit resolution
	DEFault	5.5 digit resolution
	MINimum	3.5 digit resolution
	MAXimum	6.5 digit resolution

Query

:DIGits?	Query display resolution
:DIGits? DEFault	Query *RST default resolution
:DIGits? MINimum	Query lowest allowable display resolution
:DIGits? MAXimum	Query largest allowable display resolution

Description

This command is used to set the display resolution. Note that you can instead use rational numbers. For example, to select 4.5 digit resolution, you can send a parameter value of 4.5 (instead of 5). The SourceMeter rounds the rational number to an integer.

:ENABle <b>

:DISPlay:ENABle <b> — Control display circuitry

Parameters

<b> =	0 or OFF	Disable display circuitry
	1 or ON	Enable display circuitry

Query

:ENABle? Query state of display

Description

This command is used to enable and disable the front panel display circuitry. When disabled, the instrument operates at a higher speed. While disabled, the display is frozen with the following message:

FRONT PANEL DISABLED
Press LOCAL to resume.

As reported by the message, all front panel controls (except LOCAL and OUTPUT OFF) are disabled. Normal display operation can be resumed by using the :ENABle command to enable the display or by putting the Model 2420 into local.

:ATTRibutes?

:DISPlay[:WINDow[1]]:ATTRibutes? Query attributes; top display
:DISPlay:WINDow2:ATTRibutes? Query attributes; bottom display

Description This query command is used to determine which characters on the display are blinking and which are not. The response message provides that status of each character position for the specified display. The primary display consists of 20 characters and the secondary display consists of 32 characters.

1 = Character is blinking
0 = Character is not blinking

For example, assume the following menu is displayed with the SAVESETUP option blinking:

MAIN MENU
SAVESETUP COMMUNICATION CAL >

The response message for :disp:attr? (top display) will result in 20 zeroes as follows:

00000000000000000000

The response message for :disp:wind2:attr? (bottom display) will display ones at the character positions for SAVESETUP as follows:

11111111100000000000000000000000

:CNDisplay

:DISPlay:CNDisplay Return to source-measure display state

Description This action command is used to return the instrument to the source-measure display state (source, measure and compliance readings displayed). For example, if a menu structure is presently being displayed, this command will exit the menu and return to the source-measure display state.

Read display

:DATA?

:DISPlay[:WINDow[1]]:DATA? Read top display
:DISPlay:WINDow2:DATA? Read bottom display

Description These query commands are used to read what is currently being displayed on the top and bottom displays. After sending one of these commands and addressing the Model 2420 to talk, the displayed data (message or reading) will be sent to the computer.

Define :TEXT messages

:DATA <a>

:DISPlay[:WINDow[1]]:TEXT:DATA <a> — Define message; top display
:DISPlay:WINDow2:TEXT:DATA <a> — Define message; bottom display

Parameters <a> = ASCII characters for message

Types: String 'aa...a' or "aa...a"
Indefinite Block #0aa...a
Definite Block #XYaa...a

where Y = number of characters in message:
Up to 20 for top display
Up to 32 for bottom display
X = number of digits that make up Y (1 or 2)

Query :DATA? Query the defined text message

Description These commands define text messages for the display. A message can be as long as 20 characters for the top display, and up to 32 characters for the bottom display. A space is counted as a character. Excess message characters result in an error.

An indefinite block message must be the only command in the program message or the last command in the program message. If you include a command after an indefinite block message (on the same line), it will be treated as part of the message and is displayed instead of executed.

:STATe <b>

:DISPlay[:WINDow[1]]:TEXT:STATe <b> — Control message; top display
:DISPlay:WINDow2:TEXT:STATe <b> — Control message; bottom display

Parameters <b> = 0 or OFF — Disable text message for specified display
1 or ON — Enable text message for specified display

Query :STATe? Query state of message mode for specified display

Description These commands enable and disable the text message modes. When enabled, a defined message is displayed. When disabled, the message is removed from the display.

GPIB Operation — A user defined text message remains displayed only as long as the instrument is in remote. Taking the instrument out of remote (by pressing the LOCAL key or sending LOCAL 27) cancels the message and disables the text message mode.

RS-232 Operation — A user defined test message can be canceled by sending the :SYSTem:LOCal command or pressing the LOCAL key.

FORMat subsystem

The commands for this subsystem are used to select the data format for transferring instrument readings over the bus. These commands are summarized in Table 5-4.

Data format

[:DATA] <type>[,length]

:FORMat[:DATA] <type>[,<length>] Select data format

Parameters <type>[,<length>] = ASCii ASCII format
REAL,32 IEEE754 single precision format
SREal IEEE754 single precision format

NOTE *<length> is not used for the ASCii or SREal parameters. It is optional for the REAL parameter. If you do not use <length> with the REAL parameter, the <length> defaults to 32 (single precision format).*

Query [:DATA]? Query data format

Description This command is used to select the data format for transferring readings over the bus. Only the ASCII format is allowed over the RS-232 interface. This command only affects the output of READ?, FETCh?, MEASure?, TRACe:DATA?, CALC1:DATA? and CALC2:DATA? over the GPIB. All other queries are returned in the ASCII format.

NOTE *Regardless of which data format for output strings is selected, the SourceMeter will only respond to input commands using the ASCII format.*

ASCII format

The ASCII data format is in a direct readable form for the operator. Most BASIC languages easily convert ASCII mantissa and exponent to other formats. However, some speed is compromised to accommodate the conversion. Figure 5-1 shows an example ASCII string that includes all the data elements (see :ELEMents).

Figure 5-1 also shows the byte order of the data string. Data elements not specified by the :ELEMents command are simply not included in the string.

Keep in mind that the byte order can only be reversed for the binary format (see :BORDer command).

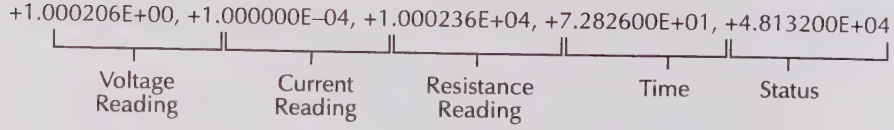


Figure 5-1 ASCII data format

IEEE754 single precision format

REAL,32, or SREal will select the binary IEEE754 single precision data format. Figure 5-2 shows the normal byte order format for each data element. For example, if three valid elements are specified, the data string for each reading conversion is made up of three 4-byte data blocks. Note that the data string for each reading conversion is preceded by a 2-byte header that is the binary equivalent of an ASCII # sign and 0. Figure 5-2 does not show the byte for the terminator that is attached to the end of each data string.

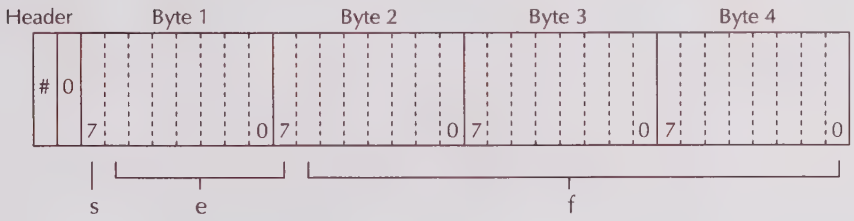


Figure 5-2
IEEE754 single precision data format (32 data bits)

s = sign bit (0 = positive, 1 = negative)
e = exponent bits (8)
f = fraction bits (23)

Normal byte order shown. For swapped byte order, bytes sent in reverse order: Header, Byte 4, Byte 3, Byte 2, Byte 1

The header and terminator are sent only once for each READ?.

During binary transfers, never un-talk the Model 2420 until after the data is read (input) to the computer. Also, to avoid erratic operation, the readings of the data string (and terminator) should be acquired in one piece. The header (#0) can be read separately before the rest of the string.

The number of bytes to be transferred can be calculated as follows:

Bytes=2+(Rdgs × 4) + 1

where 2 is the number of bytes for the header (#0).
Rdgs is the product of the number of selected data elements, arm count, and trigger count.
4 is the number of bytes for each reading.
1 is the byte for the terminator.

For example, assume the SourceMeter is configured to perform 10 source-measure operations and send the 10 current measurements to the computer using the binary format.

Bytes = 2 + (10 x 4) + 1
= 43

The following programming example shows how to properly send this binary string to the computer and display the readings.

Program Example

```
                                                              Comments
CLS
OPEN "ieee" For OUTPUT AS #1                                  ' 1
OPEN "ieee" FOR INPUT AS #2                                   ' 2
OPEN "ieee" FOR BINARY AS #3                                  ' 3

PRINT #1, "interm crlf"                                       ' 4
PRINT #1, "outterm lf"                                        ' 5

PRINT #1, "remote 24"                                         ' 6
PRINT #1, "clear 24"                                          ' 7
PRINT #1, "output 24; *rst; *cls"                             ' 8
PRINT #1, "output 24; :outp:stat on"                          ' 9
PRINT #1, "output 24; :form:elem curr; bord swap; data sre"   '10
PRINT #1, "output 24; :trig:coun 10"                          '11

PRINT #1, "output 24; :read?"                                 ' 12
PRINT #1, "enter 24 #43"                                      ' 13
GET #3, , A%                                                  '14
FOR H = 1 to 10                                               ' 15
    GET #3, , rdg!                                            ' 16
    PRINT rdg!; "amps"                                        ' 17
NEXT H                                                        ' 18
GET #3, ,A%                                                   ' 19
PRINT #1, "output 24; trig:coun?"                             ' 20
PRINT #1, "enter 24"                                          ' 21
INPUT #2, A$
PRINT
PRINT A$; "binary readings acquired and displayed"
END
```

Comments

1. Open output driver file.
2. Open input driver file.
3. Open binary driver file.
4. Set input terminator for CRLF.
5. Set output terminator for LF.
6. Place SourceMeter in remote.
7. Clear GPIB interface.
8. Return to default configuration.
9. Turn source output on.
10. Select binary data format (swapped) for current readings.
11. Set trigger count to 10.

12. Perform 10 source-measure operations.
13. Address 2420 to talk; sends 43 bytes (two for the #0 header, 40 for the 10 readings and one for the terminator).
14. Get the #0 header of the data string.
15-18. Get and print the 10 floating point readings.
19. Get the terminator for the data string.
20. Query the trigger count.

Data elements

:ELEMents <item list>

:FORMat:ELEMents <item list> Specify data elements for data string

Parameters

<item list> =		
	VOLTage	Includes voltage reading
	CURRent	Includes current reading
	RESistance	Includes resistance reading
	TIME	Includes timestamp
	STATus	Includes status information

NOTE *Each item in the list must be separated by a comma (i.e., :ELEMents VOLTage, CURRent, RESistance).*

Query :ELEMents? Query elements in data string

Description This command is used to specify the elements to be included in the data string in response to the following queries:

:FETCh?
:READ?
:MEASure?
:TRACe:DATA?

You can specify from one to all five elements. Each element in the list must be separated by a comma (,). These elements (shown in Figure 5-1) are explained as follows:

NOTE *An overflow reading reads as +9.9E37.*

The example ASCII reading string shown in Figure 5-1 shows a measurement of a 10kΩ resistor, with the SourceMeter configured to Source I Measure V. The voltage reading is the voltage measurement (1.000236V), the current reading is the current source value (100µA), the resistance reading is 10.00236kΩ, and the operation was performed 72.826 seconds after the SourceMeter was turned on (or after timestamp was reset).

VOLTage — This element provides the voltage measurement or the programmed voltage source reading. If sourcing voltage and measuring voltage, this element will provide the voltage measurement (measure reading takes priority over source reading). If voltage is not sourced or measured, the NAN (not a number) value of +9.91e37 is used.

CURRent — This element provides the current measurement or the programmed current source reading. If sourcing current and measuring current, this element will provide the current measurement (measure reading takes priority over source reading). If current is not sourced or measured, the NAN (not a number) value of +9.91e37 is used.

RESistance — This element provides the resistance measurement. If resistance is not measured, the NAN (not a number) value of +9.91e37 is used.

TIME — A timestamp is available to reference each group of readings to a point in time. The relative timestamp operates as a timer that starts at zero seconds when the instrument is turned on or when the relative timestamp is reset (:SYSTem:TIME:RESet). The timestamp for each reading sent over the bus is referenced, in seconds, to the start time. After 99,999.999 seconds, the timer resets back to zero and starts over.

Timestamp is also available for buffer readings. Timestamp can be referenced to the first reading stored in the buffer (absolute format) which is timestamped at 0 seconds, or can provide the time between each reading (delta format). The :TRACe:TSTamp:FORMat command is used to select the absolute or delta format.

STATus — A status word is available to provide status information concerning SourceMeter operation. The 20-bit status word is sent in a decimal form and has to be converted by the user to the binary equivalent to determine that state of each bit in the word. For example, if the status value is 65, the binary equivalent is 00000000000001000001. Bits 0 and 6 are set.

The significance of each status bit is explained as follows:

Bit 0 (OFLO) — Set to 1 if measurement was made while in over-range.
Bit 1 (Filter) — Set to 1 if measurement was made with the filter enabled.
Bit 2 (Front/Rear) — Set to 1 if FRONT terminals are selected.
Bit 3 (Compliance) — Set to 1 if in "real" compliance.
Bit 4 (OVP) — Set to 1 if the over voltage protection limit was reached.
Bit 5 (Math) — Set to 1 if math expression (calc1) is enabled.
Bit 6 (Null) — Set to 1 if Null is enabled.
Bit 7 (Limits) — Set to 1 if a limit test (calc2) is enabled.
Bits 8 and 9 (Limit Results) — Provides limit test results:

Bit 9	Bit 8	
0	0	All limit tests passed
0	1	Limit Test 1 failed
1	0	Limit Test 2 failed
1	1	Limit Test 3 failed

Bit 10 (Auto-ohms) — Set to 1 if auto-ohms enabled.
Bit 11 (V-Meas) — Set to 1 if V-Measure is enabled.
Bit 12 (I-Meas) — Set to 1 if I-Measure is enabled.
Bit 13 (Ω-Meas) — Set to 1 if Ω-Measure is enabled.
Bit 14 (V-Sour) — Set to 1 if V-Source used.
Bit 15 (I-Sour) — Set to 1 if I-Source used.
Bit 16 (Range Compliance) — Set to 1 if in "range" compliance.
Bit 17 (Offset Compensation) — Set to 1 if Offset Compensated Ohms is enabled.
Bits 18 and 19 — Always 0.

Example reading string

The example ASCII reading string shown in Figure 5-1 shows a measurement of a 10kΩ resistor, with the SourceMeter configured to Source I Measure V. The voltage reading is the voltage measurement (1.000236V), the current reading is the current source value (100μA), the resistance reading is 10.00236kΩ, and the operation was performed 72.826 seconds after the SourceMeter was turned on (or after timestamp was reset). The status reading of 48,132 indicates that bits 2, 10, 11, 12, 13 and 15 of the status word are set.

Byte order

:BORDer <name>

:FORMat:BORDer <name> — Specify binary byte order

Parameters

<name> =		
NORMal	Normal byte order for binary formats
SWAPped	Reverse byte order for binary formats

Query :BORDer? Query byte order

Description This command is used to control the byte order for the IEEE754 binary formats. For normal byte order, the data format for each element is sent as follows:

Byte 1 Byte 2 Byte 3 Byte 4 (Single precision)

For reverse byte order, the data format for each element is sent as follows:

Byte 4 Byte 3 Byte 2 Byte 1 (Single precision)

The "#0" Header is not affected by this command. The Header is always sent at the beginning of the data string for each measurement conversion.

The ASCII data format can only be sent in the normal byte order. The SWAPped selection is simply ignored when the ASCII format is selected.

NOTE: The SWAPped byte order must be used when transmitting binary data to any IBM PC compatible computer.

Status register format

:SREGister <name>

:FORMat:SREGister <name> — Set data format for reading status registers

Parameters

<name> =	
ASCii	Decimal format
Hexadecimal	Hexadecimal format
OCTal	Octal format
BINary	Binary format

Query :SREGister? Query format for reading status registers

Description Query commands are used to read the contents of the status event registers. This command is used to set the response message format for those query commands.

When a status register is queried, the response message is a value that indicates which bits in the register are set. For example, if bits B5, B4, B2, B1, and B0 of a register are set (110111), the following values will be returned for the selected data format:

ASCii	55	(decimal value)
Hexadecimal	#H37	(hexadecimal value)
OCTal	#Q67	(octal value)
BINary	#B110111	(binary value)

See "Common commands" in Section 4 and "Status subsystem" in this section for more information.

OUTPut subsystem

This subsystem is used to control the output of the selected source, and the interlock. These commands are summarized in Table 5-5.

Turn source on or off

[:STATe] <b>

:OUTPut[1][:STATe] <b> Turn source on or off

Parameters <b> = 0 or OFF Turn source off (standby)
1 or ON Turn source on (operate)

Query :OUTPut? Query state of source

Description This command is used to turn the source output on or off. Measurements cannot be made while the source is off.

Turning the source off places the SourceMeter in the idle state. The only exception to this is when source auto clear is enabled. In this mode, the source turns on during each source phase of the SDM cycle and then turns off after each measurement (see :SOURce:CLEar:AUTO in SOURce Subsystem).

NOTE The :SOURce:CLEar command will also turn the source off.

Interlock control

:STATe <b>

:OUTPut[1]:INTerlock:STATe <b> Control hardware interlock

Parameters <b> = 0 or OFF Disable interlock
1 or ON Enable interlock

Query :STATe? Query state of interlock

Description This command is used to enable or disable the hardware interlock. When enabled, the source cannot be turned on unless the interlock line (pin 8 of the rear panel Interlock - Digital I/O connector) is pulled to a logic low state. When the interlock line goes to a logic high state, the source turns off. See "Interlock and digital I/O" in Section 3 for details using interlock with a test fixture.

When disabled, the logic level on the interlock line has no effect on the output state of the source.

:TRIPped?

:OUTPut[1]:INTerlock:TRIPped?

Description This query command is used to determine if the enabled interlock has been tripped. The tripped condition ("1") means that the source can be turned on (interlock line at logic low level).

A "0" will be returned if the source cannot be turned on (interlock line at logic high level).

Output-off states

:SMODe

:OUTPut[1]:SMODe <name> Select output-off mode

Parameters

<name>	=	HIMPedance	Disconnect Input/Output
		NORMal	Normal output-off state
		ZERO	Zero output-off state
		GUARd	Guard output-off state

Query :SMODe? Query output off mode

Description This command is used to select the output-off state of the SourceMeter. With HIMPedance selected, the output relay opens when the source is turned off. This disconnects external circuitry from the SourceMeter Input/Output.

NOTE: To prevent excessive wear on the output relay, do not use the HIMPedance mode for tests that turn the output on and off frequently.

With NORMal selected, the V-Source is selected and set to 0V when the output is turned off. Compliance is set to 0.5% full scale of the present current range.

In the ZERO output-off state when the V-Source OUTPUT is turned off, the V-Source is set to 0V and current compliance is not changed. When the I-Source OUTPUT is turned off, the V-Source mode is selected and set to 0V. Current compliance is set to the programmed Source I value or to 0.5% full scale of the present current range, whichever is greater.

The ZERO output-off state is typically used with the V-Source and Output Auto-On (see the :SOURce1:CLEar:AUTO command) to generate voltage waveforms that alternate between 0V and the programmed output-on voltage.

With GUARd selected, the I-Source is selected and set to 0A. Voltage compliance is set to 0.5% full scale of the present voltage range. This output-off state should be used when performing 6-wire guarded ohms measurements or for any other load that uses an active source.

NOTE: For more information on output-off states, see "Configure output; output-off states" in Section 3.

:ROUTe subsystem

The ROUTe subsystem is summarized in Table 5-6.

Select input jacks

TERMinals <name>

:ROUTe:TERMinals <name> Select front or rear panel in/out jacks

Parameters

<name> =	FRONt	Front panel in/out jacks
	REAR	Rear panel in/out jacks

Query :TERMinals? Query state of front/rear switch setting

Description This command is used to select which set of input/output terminals to enable (front panel or rear panel).

For SCPI compatibility, this command is preferred over :SYSTem:FRSWitch.

SENSe1 subsystem

The Sense1 subsystem is used to configure and control the measurement functions of the Model 2420. Many of the commands are global, where a single command affects all functions. Some commands are unique to a specific function. For example, you can program a unique range setting for each basic function (amps, volts and ohms).

A function does not have to be selected before you can program its various configurations. Whenever a programmed function is selected, it assumes the programmed states.

The commands for this subsystem are summarized in Table 5-7.

Select measurement functions

:CONCurrent <b>

[:SENSe[1]]:FUNCtion:CONCurrent <b> Control concurrent measurements

Parameters <b> = 0 or OFF Disable concurrent measurements
1 or ON Enable concurrent measurements

Query :CONCurrent? Query state of concurrent measurements

Description This command is used to enable or disable the ability of the instrument to measure more than one function simultaneously. When enabled, the instrument will measure the functions that are selected (see [:ON], :OFF and :ALL).

When disabled, only one measurement function can be enabled. When making the transition from :CONCurrent ON to :CONCurrent OFF, the voltage (VOLT:DC) measurement function will be selected. All other measurement functions will be disabled. Use the :FUNCTion[:ON] command to select one of the other measurement functions.

[:ON] <function list>

:OFF <function list>

[:SENSe[1]]:FUNCtion[:ON] <function list> Specify functions to be enabled
[:SENSe[1]]:FUNCtion:OFF <function list> Specify functions to be disabled

Parameters <function list> = "CURRent[:DC]" Amps measurement function
"VOLTage[:DC]" Volts measurement function
"RESistance" Ohms measurement function

NOTE *Each function in the list must be enclosed in quotes (double or single) and separated by a comma (i.e., :func:on "volt", "curr").*

Query [:ON]? Query functions that are enabled
:OFF? Query functions that are disabled

Description When concurrent measurements are enabled, these commands are used to enable or disable functions to be measured. The [:ON] command is used to include (enable) one or more measurement functions in the list, and the :OFF command is used remove (disable) one or more functions from the list.

Note that each function specified in the list must be enclosed in single or double quotes, and functions must be separated by commas (,). Examples:

:FUNCtion "VOLTage", "CURRent" Enable volts and amps functions
:FUNCtion:OFF 'VOLTage', 'CURRent' Disable volts and amps functions

Note that there is a stand-alone command that can be used to enable or disable all three measurement functions (see :ALL).

If concurrent measurements (see :CONCurrent) are disabled, the :ON command can only turn on one function at a time.

ALL

[:SENSe[1]]:FUNCtion[:ON]:ALL Enable all measurement functions
[:SENSe[1]]:FUNCtion:OFF:ALL Disable all measurement functions

Description This command is used to enable or disable all measurement functions.

When enabled (:ON:ALL), amps, volts and ohms measurements will be performed simultaneously if concurrent measurements (see :CONCurrent) are enabled. If concurrent measurements are disabled, only the ohms function will be enabled.

The :OFF:ALL command disables all measurements.

:COUNt?

[:SENSe[1]]:FUNCtion[:ON]:COUNt? Query number of functions enabled
[:SENSe[1]]:FUNCtion:OFF:COUNt? Query number of functions disabled

Description This query command is used to determine the number of functions that are enabled or disabled.

When :ON:COUNt? is sent, the response message will indicated then number of functions that are enabled.

When :OFF:COUNt? is sent, the response message will indicate the number of functions that are disabled.

:STATe? <name>

[:SENSe[1]]:FUNCtion:STATe <name> Query state of specified function

Parameters

<name> =	"CURRent[:DC]"	Amps measurement function
	"VOLTage[:DC]"	Volts measurement function
	"RESistance"	Ohms measurement function

NOTE *The function name must be enclosed in double or single quotes (i.e., :func:stat? "volt").*

Description This command is used to query the state of the specified measurement function. A returned response message of "0" indicates that the specified function is disabled, while a "1" indicates that the function is enabled.

:RESistance:MODE <name>

[:SENSe[1]]:RESistance:MODE <name> Select ohms measurement mode

Parameters <name> = MANual Manual ohms mode
AUTO Auto ohms mode

Query :MODE? Query ohms mode

Description This command is used to select the ohms measurement mode. With MANual ohms selected, the user must configure the source and measure aspects of the operation. When the ohms function is selected, the ohms reading is simply the result of the V/I calculation.

Range changes cannot be made in manual ohms.

With AUTO ohms selected, the SourceMeter will be configured to Source I Measure V when the ohms function is selected. The current source value and voltage measurement range used depend on the ohms measurement range that is selected.

See "Basic Ohms Measurement Procedure" in Section 2 for details on manual and auto ohms.

:RESistance:OCOMpensated <b>

[:SENSe[1]]:RESistance:OCOMpensated <b> Control offset-compensated ohms

Parameters <b> = 1 or ON Enable offset compensation
0 or OFF Disable offset compensation

Query :OCOMpensated? Query state of offset compensation

Description This command is used to enable or disable offset-compensated ohms. When using the auto ohms measurement mode, the current source level is automatically set. When using the manual ohms measurement mode, you must set the source (V or I) output level.

See "Offset compensated Ω" in Section 2 for details on making offset-compensated ohms measurements.

NOTE *Offset-compensated ohms will disable when the :MEASure? command (for the resistance function) or the :CONFigure:RESistance command is sent.*

Select measurement range

Notes:

1. You cannot select a current measurement range if sourcing current. Conversely, you cannot select a voltage measurement range if sourcing voltage. Also, autorange cannot be enabled for those source-measure configurations. The programmed source range determines measurement range.
2. You cannot select an ohms measurement range if in manual ohms (you must be in auto ohms).
3. The highest current measurement range that can be selected is limited by the current compliance range. For example, if current compliance is set for 50mA (100mA range), then the highest available current measurement range is 100mA. Similarly, the highest voltage measurement range is limited by the voltage compliance range.
4. When on the 60V V-Source range, the maximum I-Measure range is 1A.
5. When on the 3A I-Source range, the maximum V-Measure range is 20V.

[:UPPer] <n>

[:SENSe[1]]:CURRent[:DC]:RANGe[:UPPer] <n>|UP|DOWN	Select range for amps
[:SENSe[1]]:VOLTage[:DC]:RANGe[:UPPer] <n>|UP|DOWN	Select range for volts
[:SENSe[1]]:RESistance:RANGe[:UPPer] <n>|UP|DOWN	Select range for ohms

Parameters

<n> =	-3.15 to 3.15	Expected reading in amps
	-63 to 63	Expected reading in volts
	0 to 2.1e7	Expected reading in ohms
	DEFault	1.05e-4 (amps)
		21 (volts)
		2.1e5 (ohms)
	MINimum	0 (10µA, 200mV, or 2Ω range)
	MAXimum	3.15 (amp), 63 (volt), 2.1e7 (ohms)

Query

:RANGe?	Query measurement range
:RANGe? DEFault	Query *RST default range
:RANGe? MINimum	Query lowest range (returns 0)
:RANGe? MAXimum	Query highest range

Description

This command is used to manually select the measurement range for the specified measurement function. The range is selected by specifying the expected reading. The instrument will then go to the most sensitive reading that will accommodate that reading. For example, if you expect a reading of approximately 50mV, then simply let <n> = 0.05 (or 50e-3) in order to select the 200mV range.

Measurement ranges can instead be automatically selected by the instrument (see :AUTO).

:AUTO <b>

[:SENSe[1]]:CURRent[:DC]:RANGe:AUTO <b> — Control auto ranging for amps
[:SENSe[1]]:VOLTage[:DC]:RANGe:AUTO <b> — Control auto ranging for volts
[:SENSe[1]]:RESistance:RANGe:AUTO <b> — Control auto ranging for ohms

Parameters

<b> =	0 or OFF	Disable auto range
	1 or ON	Enable auto range

Query :AUTO? Query state of auto range

Description This command is used to control auto ranging. With auto ranging enabled, the instrument automatically goes to the most sensitive range to perform the measurement.

When this command is used to disable auto range, the instrument remains at the automatically selected range. When a range is manually selected (see previous command) auto range disables.

Set compliance limit

[:LEVel] <n>

[:SENSe[1]]:CURRent[:DC]:PROTection[:LEVel] <n>	Set current compliance
[:SENSe[1]]:VOLTage[:DC]:PROTection[:LEVel] <n>	Set voltage compliance

Parameters

<n> =	-3.15 to 3.15	Specify current compliance limit
	-63 to 63	Specify voltage compliance limit
	DEFault	105µA, 21V
	MINimum	-3.15A, -63V
	MAXimum	3.15A, 63V

Query

:LEVel?	Query compliance value
:LEVel? DEFault	Query *RST default compliance
:LEVel? MINimum	Query minimum allowable compliance
:LEVel? MAXimum	Query maximum allowable compliance

Description This command is used to set compliance limits. A current compliance limit is set for the V-Source, and a voltage compliance limit is set for the I-Source. The SourceMeter cannot source levels that exceed these specified limits.

The :SENSe:CURRent:PROTection[:LIMit] command is used to set the current compliance for the V-Source and the :SENSe:VOLTage:PROTection[:LIMit] command is used to set the voltage compliance for the I-Source.

NOTE *You cannot set compliance less than 0.1% of the present measurement range.*

:TRIPped?

[:SENSe[1]]:CURRent[:DC]:PROTection:TRIPped?	Query current compliance state
[:SENSe[1]]:VOLTage[:DC]:PROTection:TRIPped?	Query voltage compliance state

Description This command is used to determine if the source is in compliance. If a "1" is returned, then the source is in compliance. A "0" indicates that the source is not in compliance.

The :CURRent:PROTection:TRIPped? command is used to check the compliance state of the V-Source, and the :VOLTage: PROTection:TRIPped? command is used to check the compliance state of the I-Source.

Set measurement speed

:NPLCycles <n>

[:SENSe[1]]:CURRent[:DC]:NPLCycles <n> Set speed (PLC)
[:SENSe[1]]:VOLTage[:DC]:NPLCycles <n> Set speed (PLC)
[:SENSe[1]]:RESistance:NPLCycles <n> Set speed (PLC)

Parameters

<n> =	0.01 to 10	Power-line cycles per integration
	DEFault	1
	MINimum	0.01
	MAXimum	10

Query

:NPLCycles?	Query programmed PLC value
:NPLCycles? DEFault	Query *RST default PLC
:NPLCycles? MINimum	Query minimum PLC
:NPLCycles? MAXimum	Query maximum PLC

Description

This command is used to set the integration period (speed) for measurements. NPLC (Number of Power Line Cycles) expresses the integration period by basing it on the power line frequency. For example, for a PLC of 1, the integration period would be 1/60 (for 60Hz line power) which is 16.67 msec.

Note that this is a global command. Thus, if you set the speed for voltage measurements to 10 PLC, then current and resistance will also set to 10 PLC.

Configure and control filter

:TCONtrol <name>

[:SENSe[1]]:AVERage:TCONtrol <name> Select filter type

Parameters

<name> =	REPeat	Repeating filter
	MOVing	Moving filter

Query

:TCONtrol? Query filter type

Description

This command is used to select the type of averaging filter (REPeat or MOVing). These filter types are explained in Section 3 (see "Filter Modes").

The number of readings that are averaged by the filter is set with the :AVERage:COUNt command. The :AVERage:STATe command is used to enable or disable the filter.

:COUNt <n>

[:SENSe[1]]:AVERage:COUNt <n> Specify filter count

Parameters

<n> =	to 100	Specify filter count
	DEFault	10
	MINimum	1
	MAXimum	100

Query

:COUNt?	Query filter count
:COUNt? DEFault	Query the *RST default filter count
:COUNt? MINimum	Query the lowest allowable filter count
:COUNt? MAXimum	Query the largest allowable filter count

Description These commands are used to specify the filter count. In general, the filter count is the number of readings that are acquired and stored in the filter buffer for the averaging calculation. The larger the filter count, the more filtering that is performed.

[:STATe] <b>

[:SENSe[1]]:AVERage[:STATe] <b> Enable or disable filter

Parameters

<b> =	0 or OFF	Disable digital filter
	1 or ON	Enable digital filter

Query :STATe? Query state of digital filter

Description These commands are used to enable or disable the digital averaging filter. When enabled, voltage, current and resistance readings are filtered according to how the filter is configured.

SOURce subsystem

This subsystem is used configure and control the I-Source and V-Source, and to set the logic level (high or low) of each digital output line. The commands for this subsystem are summarized in Table 5-8.

SOURce[1]

Use the following commands to configure and control the I-Source and V-Source. At the end of this subsystem are program examples of sweeps and lists.

Control source output-off

[:IMMediate]

:SOURce[1]:CLEar[:IMMediate] — Turn source output off

Description This command is used to turn off the source output. The output will turn off after all programmed source-measure operations are completed and the instrument returns to the idle state.

Note that if auto output-off is enabled (see next command), the source output will automatically turn off.

:AUTO

:SOURce[1]:CLEar:AUTO <b> — Control auto output-off

Parameter	<b> = 1 or ON	Enable auto output-off
	= 0 or OFF	Disable auto output-off
Query	:AUTO?	Query state of auto output-off

Description This command is used to control auto output-off for the source. With auto output-off enabled, an :INITiate (or :READ? or MEASure?) will start source-measure operation. The output will turn on at the beginning of each SDM (source-delay-measure) cycle and turn off after each measurement is completed.

With auto output-off disabled, the source output must be on before an :INITiate or :READ? can be used to start source-measure operation. The :MEASure? command will automatically turn on the source output. Once operation is started, the source output will stay on even after the instrument returns to the idle state. Auto output-off disabled is the *RST and :SYSTem:PRESet default.

WARNING **With auto output-off disabled, the source output will remain on after all programmed source-measure operations are completed. Beware of hazardous voltage that may be present on the output terminals.**

Select function mode

[:MODE] <name>

:SOURce[1]:FUNCtion[:MODE] <name> — Select source mode

Parameters	<name> = VOLTage	Select voltage mode
	CURRent	Select current mode
	MEMory	Select memory mode

Query [:MODE]? Query selected source

Description This command is used to select the source mode. With VOLTage selected, the V-Source will be used, and with CURRent selected, the I-Source will be used.

With MEMory selected, a memory sweep can be performed. Operating set-ups (up to 100) saved in memory can be sequentially recalled. This allows multiple source/measure functions to be used in a sweep.

Select sourcing mode

:MODE <name>

:SOURce[1]:CURRent:MODE <name> Select DC sourcing mode for I-Source
:SOURce[1]:VOLTage:MODE <name> Select DC sourcing mode for V-Source

Parameters	<name> =	FIXed	Select fixed sourcing mode
		LIST	Select list sourcing mode
		SWEep	Select sweep sourcing mode

Query :MODE? Query DC sourcing mode

Description This command is used to select the DC sourcing mode for the specified source. The three modes are explained as follows:

FIXed — In this DC sourcing mode, the specified source will output a fixed level. Use the :RANGe and :AMPLitude commands to specify the fixed source level (see "Select range" and "Set amplitude for fixed source").

LIST — In this mode, the source will output levels that are specified in a list. See "Configure list" for commands to define and control the execution of the list.

SWEep — In this mode, the source will perform a voltage, current or memory sweep. See "Configure voltage and current sweeps" and "Configure memory sweep" for commands to define the sweep.

NOTE *The sourcing mode will default to FIXed whenever the SourceMeter goes to the local state.*

Select range

:RANGe <n>

:SOURce[1]:CURRent:RANGe <n> Select range for I-Source
:SOURce[1]:VOLTage:RANGe <n> Select range for V-Source

Parameters	<n> =	-3.15 to 3.15	Specify I-Source level (amps)
		-63 to 63	Specify V-Source level (volts)
		MINimum	1μA range (I-Source)
			200mV range (V-Source)
		MAXimum	3A range (I-Source)
			60V range (V-Source)
		DEFault	100μA range (I-Source)
			20V range (V-Source)
		UP	Select next higher range
		DOWN	Select next lower range

Query

:RANGe?	Query range for specified source
:RANGe? DEFault	Query *RST default source range
:RANGe? MINimum	Query lowest source range (returns 0)
:RANGe? MAXimum	Query highest source range

Description

This command is used to manually select the range for the specified source. Range is selected by specifying the approximate source magnitude that you will be using. The instrument will then go to the lowest range that can accommodate that level. For example, if you expect to source levels around 3V, send the following command:

:SOURce:VOLTage:RANGe 3

The above command will select the 20V range for the V-Source.

As listed in the "Parameters", you can also use the MINimum, MAXimum and DEFault parameters to manually select the source range. The UP parameter selects the next higher source range, while DOWN selects the next lower source range.

Note that source range can be selected automatically by the instrument (see next command).

:AUTO <b>

:SOURce[1]:CURRent:RANGe:AUTO <b>	Select auto range for I-Source
:SOURce[1]:VOLTage:RANGe:AUTO <b>	Select auto range for V-Source

Parameters

<b> =	0 or OFF	Disable auto range
	1 or ON	Enable auto range

Query

AUTO? Query state of auto range

Description

This command is used to enable or disable auto range for the specified source. When enabled, the instrument will automatically select the most sensitive range for the specified source level. When disabled, the instrument will use the range that the instrument is currently on.

Auto range will be disabled if a fixed range is selected (see previous command).

Both *RST and :SYSTem:PREset enables source auto range. When the SourceMeter goes into the local state, source auto range disables.

Set amplitude for fixed source

[:IMMediate][:AMPLitude] <n>

:SOURce[1]:CURRent[:LEVel][:IMMediate][:AMPLitude] <n> Set fixed I-Source amplitude immediately
:SOURce[1]:VOLTage[:LEVel][:IMMediate][:AMPLitude] <n> Set fixed V-Source amplitude immediately

Parameters

<n> =	-3.15 to 3.15	Set I-Source amplitude (amps)
	-63 to 63	Set V-Source amplitude (volts)
	MINimum	-3.15A or -63V
	MAXimum	3.15A or 63V
	DEFault	0A or 0V

Query

:CURRent?	Query programmed amplitude of I-Source
:CURRent? DEFault	Query *RST default amplitude
:CURRent? MINimum	Query lowest allowable amplitude
:CURRent? MAXimum	Query highest allowable amplitude
:VOLTage?	Query programmed amplitude of V-Source
:VOLTage? DEFault	Query *RST default amplitude
:VOLTage? MINimum	Query lowest allowable amplitude
:VOLTage? MAXimum	Query highest allowable amplitude

Description This command is used to immediately update the amplitude of a fixed source. This command is not valid if the list or sweep mode is selected.

NOTE *The sourcing :MODE command is used to select a fixed source (see "Select sourcing mode").*

If a manual source range is presently selected, then the specified amplitude cannot exceed that range. For example, if the V-Source is on the 2V range (auto range disabled), you will not be able to set the V-Source amplitude to 3V. In auto range, the amplitude can be set to any level that is within the capabilities of the source.

The MINimum and MAXimum parameters are only valid if the highest source range (3A or 60V) is presently selected. Sending the MINimum or MAXimum parameters on a lower source range will generate error -221 (Setting Conflict).

:TRIGgered[:AMPLitude] <n>

:SOURce[1]:CURRent[:LEVel]:TRIGgered[:AMPLitude] <n> Set fixed I-Source amplitude when triggered
:SOURce[1]:VOLTage[:LEVel]:TRIGgered[:AMPLitude] <n> Set fixed V-Source amplitude when triggered

Parameters

<n> =	-3.15 to 3.15	Set I-Source amplitude (amps)
	-63 to 63	Set V-Source amplitude (volts)
	MINimum	-3.15A or -63V
	MAXimum	3.15A or 63V
	DEFault	0A or 0V

Query

:TRIGgered?	Query triggered amplitude for fixed source.
:TRIGgered? DEFault	Query *RST default amplitude
:TRIGgered? MINimum	Query lowest allowable amplitude
:TRIGgered? MAXimum	Query highest allowable amplitude

Description This command performs the same as the [:IMMediate][:AMPLitude] command except that the amplitude is not updated immediately.

With this command, the amplitude is updated when the SourceMeter is triggered to perform a source-measure operation. For example, if the instrument is waiting in the trigger layer for an external trigger, the amplitude of the source will not update until that external trigger is received by the Model 2420. See "Trigger model" in Section 4 for details on trigger model operation.

The MINimum and MAXimum parameters are only valid if the highest source range (3A or 60V) is presently selected. Sending the MINimum or MAXimum parameters on a lower source range will generate error-221(Setting Conflict).

Set voltage limit

[:LEVel] <n>

:SOURce[1]:VOLTage:PROTection[:LEVel] <n> Set voltage limit for V-Source

Parameters

<n> =	-63 to 63	Specify V-Source limit
	6	Set limit to 6V
	12	Set limit to 12V
	18	Set limit to 18V
	24	Set limit to 24V
	30	Set limit to 30V
	36	Set limit to 36V
	48	Set limit to 48V
	49 to 63	Set limit to NONE
	MINimum	Set limit to 0
	MAXimum	Set limit to +63V
	DEFault	Set limit to 63V

Query

[:LIMit]?	Query limit level
[:LIMit]? DEFault	Query *RST default limit
[:LIMit]? MINimum	Query lowest allowable limit
[:LIMit]? MAXimum	Query highest allowable limit

Description This command is used to set the Over Voltage Protection (OVP) limit for the V-Source. The V-Source output will not exceed the selected limit. An exception to this is the 49 to 63 parameter values, which will allow an output voltage up to 63V. This OVP limit is also enforced when in the I-Source mode.

There are eight distinct limits that can be set: 6V, 12V, 18V, 24V, 30V, 36V, 48V, and NONE. These limits are magnitudes and are in effect for both positive and negative output voltage. You can express the limit as a positive or negative value.

If you specify a value less than 6, the 6V limit will be selected. If you specify a value that is between limits, the lower limit will be selected. For example, if you specify a value of 28, the 24V limit will be selected.

WARNING **Even with the voltage protection limit set to the lowest value (6V), NEVER touch anything connected to the terminals of the SourceMeter when the OUTPUT is ON. Always assume that a hazardous voltage (>30V rms) is present when the OUTPUT is ON.**

To prevent damage to DUT (devices under test) or external circuitry, DO NOT program the V-Source to levels that exceed the voltage protection limit.

Set delay

:DELay <n>

:SOURce[1]:DELay <n> — Manually set source delay

Parameters

<n> =	0 to 999.9999	Specify delay in seconds
	MINimum	0 seconds
	MAXimum	999.9999 seconds
	DEFault	0 seconds

Query

:DELay?	Query delay
:DELay? DEFault	Query *RST default delay
:DELay? MINimum	Query lowest allowable delay
:DELay? MAXimum	Query highest allowable delay

Description This command is used to manually set a delay (settling time) for the source. After the programmed source is turned on, this delay occurs to allow the source level to settle before a measurement is taken. Note that this delay is the same for both the I-Source and V-Source.

Do not confuse this source delay with the trigger delay. The source delay is part of the device action (SDM cycle) while the trigger delay occurs before the device action. See "Trigger model" in Section 4 for more information.

Auto delay can instead be used to automatically set the source delay (see next command).

:AUTO <b>

:SOURce[1]:DELay:AUTO <b> — Enable/disable auto delay for source

Parameters

<b> =	0 or OFF	Disable auto delay
	1 or ON	Enable auto delay

Query :AUTO? Query state of auto delay

Description This command is used to enable or disable auto delay. When enabled, the instrument will automatically select a delay period that is appropriate for the present source/measure setup configuration.

Configure voltage and current sweeps

There are two methods to configure the start and stop levels of a sweep. You can use either the :STARt and :STOP commands or you can use the :CENTer and :SPAN commands.

NOTE *In order to run a sweep, the selected source must be in the sweep sourcing mode and the trigger count should be the same as the number of source-measure points in the sweep.*

Use the :FUNCtion:MODE command to select the current or voltage source function (see "Select function mode"). Use the :CURRent:MODE or VOLTage:MODE command to select the SWEep sourcing mode (see "Select sourcing mode"). The trigger count is set using the TRIGger:COUNt command (see Trigger Subsystem).

:RANGing <name>

:SOURce[1]:SWEep:RANGing <name> Select source ranging mode

Parameters

<name> =	BEST	Use the best fixed mode
	AUTO	Use the most sensitive source range for each sweep level
	FIXed	Use the present source range for the entire sweep

Query :RANGing? Query source ranging mode

Description This command is used to select the source ranging mode for sweeps. With BEST selected, the SourceMeter will select a single fixed source range that will accommodate all the source levels in the sweep. For front panel operation, this is the BEST FIXED option.

With AUTO selected, the SourceMeter will automatically go to the most sensitive source range for each source level in the sweep. For front panel operation, this is the AUTO RANGE option.

With FIXed selected, the source remains on the range that it is presently on when the sweep is started. For sweep points that exceed the source range capability, the source will output the maximum level for that range. For front panel operation, this is the FIXED option.

:SPACing <name>

:SOURce[1]:SWEep:SPACing <name> Select scale for sweep

Parameters

<name> =	LINear	Linear scale
	LOGarithmic	Logarithmic scale

Query :SPACing? Query scale for sweep

Description This command is used to select the scale for the sweep. With LINear selected, the source-measure points in the sweep will be performed on a linear scale. With LOGarithmic selected, the source-measure points will be performed on a logarithmic scale.

:STARt <n>
:STOP <n>

:SOURce[1]:CURRent:STARt <n>	Specify start current level (current sweep)
:SOURce[1]:VOLTage:STARt <n>	Specify start voltage level (voltage sweep)
:SOURce[1]:CURRent:STOP <n>	Specify stop current level (current sweep)
:SOURce[1]:VOLTage:STOP <n>	Specify stop voltage level (voltage sweep)

Parameters

<n> =	-3.15 to 3.15	Set I-Source level (amps)
	-63 to 63	Set V-Source level (volts)
	MINimum	Greatest allowable negative level
	MAXimum	Greatest allowable positive level
	DEFault	0A or 0V

Query

:STARt?	Query start level for sweep
:STARt? DEFault	Query *RST default level
:STARt? MINimum	Query lowest allowable level
:STARt? MAXimum	Query highest allowable level
:STOP?	Query start level for sweep
:STOP? DEFault	Query *RST default level
:STOP? MINimum	Query lowest allowable level
:STOP? MAXimum	Query highest allowable level

Description

These commands are used to specify the start and stop levels for a sweep. If using a fixed (manual) source range, the sweep will be performed using a source range that will accommodate all source values (Best Fixed Range). You can use source auto range if sweeping through one or more source ranges.

When the sweep is started, the source will output the specified start level and, after the delay period of the SDM cycle, a measurement is performed.

The sweep continues until the source outputs the specified stop level. At this level, the instrument again performs another measurement (after the SDM delay) and then stops the sweep.

The source-measure points in a sweep can be set by specifying a step size (see :STEP), or by specifying the number of source-measure points in the sweep (see :POINts).

:STARt and :STOP are coupled to :CENTer and :SPAN. Thus, when start and stop values are changed, the values for center and span are affected as follows:

Center = (Start + Stop) / 2
Span = Stop - Start

:CENTer <n>
:SPAN <n>

:SOURce[1]:CURRent:CENTer <n>	Specify center point of current sweep
:SOURce[1]:VOLTage:CENTer <n>	Specify center point of voltage sweep
:SOURce[1]:CURRent:SPAN <n>	Specify span of the current sweep
:SOURce[1]:VOLTage:SPAN <n>	Specify span of the voltage sweep

Parameters

<n> =	-3.15 to 3.15	Set I-Source level (amps)
	-63 to 63	Set V-Source level (volts)
	MINimum	Greatest allowable negative level
	MAXimum	Greatest allowable positive level
	DEFault	0A or 0V

Query

:CENTer?	Query center point for sweep
:CENTer? DEFault	Query *RST default level
:CENTer? MINimum	Query lowest allowable level
:CENTER? MAXimum	Query highest allowable level
:SPAN?	Query span for sweep
:SPAN? DEFault	Query *RST default level
:SPAN? MINimum	Query lowest allowable level
:SPAN? MAXimum	Query highest allowable level

Description

A sweep can be configured by specifying center and span parameters. By specifying a center point, you can sweep through the operating point of a device. The span determines the sweep width with the operating point at the center of the sweep.

For example, assume you are testing a device that operates at 10V, and you want to sweep from 8 to 12 volts. To do this, you would specify the center to be 10V and the span to be 4 volts (12 - 8).

Use the :STEP or :POINts command to specify the number of source-measure points in the sweep.

:CENTer and :SPAN are coupled to STARt and :STOP. Thus, when center and span values are changed, the values for start and stop are affected as follows:

Start = Center - (Span / 2)
Stop = Center + (Span / 2)

:STEP <n>

:SOURce[1]:CURRent:STEP <n>	Specify step size (current sweep)
:SOURce[1]:VOLTage:STEP <n>	Specify step size (voltage sweep)

Parameters

<n> =	-3.15 to 3.15	Set I-Source level (amps)
	-63 to 63	Set V-Source level (volts)
	MINimum	Greatest allowable negative level
	MAXimum	Greatest allowable positive level
	DEFault	0A or 0V

Query

:STEP	Query step size for sweep
:STEP? DEFault	Query *RST default level
:STEP? MINimum	Query lowest allowable level
:STEP? MAXimum	Query highest allowable level

Description This command is used to specify a step size for a linear sweep. When the sweep is started, the source level changes in equal steps from the start level to the stop level. A measurement is performed at each source step (including the start and stop levels).

NOTE *This command cannot be used for a logarithmic sweep. Use the :POints command to set the source-measure points for a log sweep.*

To avoid a setting conflicts error, make sure the step size is greater than the start value and less than the stop value.

The number of source-measure points in a linear sweep can be calculated as follows:

Points = [(Stop - Start) / Step] + 1
Points = (Span / Step) + 1

An alternate way to set the source-measure points in a linear sweep is to simply specify the number of source-measure points in the sweep using the :POINts command.

Note that the :STEP and :POINts commands are coupled. Changing the step size also changes the number of source-measure points. Conversely, changing the number of source-measure points changes the step size.

:POINts <n>

:SOURce[1]:SWEep:POINts <n> — Set source-measure points for sweep

Parameters

<n> =	1 to 2500	Specify number of source-measure points
	MINimum	1
	MAXimum	2500
	DEFault	2500

Query

:POINts?	Query number of sweep points
:POINts? DEFault	Query *RST default number of sweep points
:POINts ? MINimum	Query lowest allowable number of sweep points
:POINts ? MAXimum	Query highest allowable number of sweep points

Description The :POINts command specifies the total number of source-measure points in a sweep. For a linear sweep, the source-measure points are equally spaced (stepped) between the start level and the stop level. For a log sweep, the source-measure points are equally spaced on a logarithmic scale. Note that the start and stop levels are source-measure points.

Step size for a linear sweep can be calculated as follows:

Step Size = (Stop - Start) / (Points - 1)
Step Size = Span / (Points -1)

Step size for a logarithmic sweep can be calculated as follows:

$$\text{Log Step Size} = \frac{\log 10\,(\text{Stop}) - \log 10\,(\text{Start})}{\text{Points} - 1}$$

An alternate way to set the source-measure points in a sweep is to specify the step size using the :STEP command.

Note that the :POINts and :STEP commands are coupled. Changing the number of source-measure points also changes the step size. Conversely, changing the step size changes the number of source-measure points.

:DIRection <name>

:SOURce[1]:SWEep:DIRection <name> — Set direction of sweep

Parameters

<name> =	UP	Run sweep from start to stop
	DOWn	Run sweep from stop to start

Query :DIRection? Query direction of sweep

Description Normally, a sweep is run from the start level to the stop level. The :STARt and :STOP, or :CENTer and :SPAN commands are used to set these levels.

This command lets you change the execution direction of the sweep. With DOWn selected, the sweep will begin at the stop level and end at the start level. Selecting UP restores sweep operation to the normal start to stop direction.

Configure list

:CURRent <NRf list>
:VOLTage <NRf list>

:SOURce[1]:LIST:CURRent <NRf list> — Define I-Source list
:SOURce[1]:LIST:VOLTage <NRf list> — Define V-Source list

Parameters

<NRf list> = NRf, NRf ... NRf

where NRf =	-3.15 to 3.15	I-Source value
	-63 to 63	V-Source value

Query

:CURRent?	Query I-Source list
:VOLTage?	Query V-Source list

Description These commands are used to define a list of source values (up to 100) for the list sourcing mode of operation. When operation is started, the instrument will sequentially source each current or voltage value in the list. A measurement is performed at each source level.

The following command shows the proper format for defining an I-Source list using current source values of 10mA, 130mA and 5mA:

:SOURce[1]:LIST:CURRent 0.01, 0.13, 0.005

If using manual source ranging, you can use auto range for source values that are not within a single range.

NOTE *In order to execute a source list, the selected source must be in the list sourcing mode, and the product of the arm and trigger count should be at least the same as the number of source points in the list.*

Use the :FUNCtion:MODE command to select the current or voltage source function (see "Select function mode"). Use the :CURRent:MODE or VOLTage:MODE command to select the LIST sourcing mode (see "Select sourcing mode"). The trigger count is set using the TRIGger:COUNt command (see Trigger Subsystem).

:APPend <NRf list>

:SOURce[1]:LIST:CURRent:APPend <NRf list>	Add value(s) to I-Source list
:SOURce[1]:LIST:VOLTage:APPend <NRf list>	Add value(s) to V-Source list

Parameters

<NRf list> = NRf, NRf ... NRf

where NRf =	-3.15 to 3.15	I-Source value
	-63 to 63	V-Source value

Description This command is used to add one or more values (up to 100) to a source list that already exists. The source values are appended to the end of the list. (By using multiple appended lists, up to 2500 points can be in a list.)

:POINts?

:SOURce[1]:LIST:CURRent:POINts?	Query length of I-Source list
:SOURce[1]:LIST:VOLTage:POINts?	Query length of V-Source list

Description This command is used to determine the length of the specified source list. The response message indicates the number of source values in the list.

Configure memory sweep

A memory sweep lets you perform a sweep using setups stored in up to 100 memory locations. This allows you to sweep using multiple source-measure operations and math expressions (see Calculate1 Subsystem).

NOTE *In order to run a memory sweep, the memory function must be selected, and the trigger count must be the same as the number of memory points in the sweep. Use the :FUNCtion:MODE command to select the MEMory function (see "Select function mode"). Arm count (ARM:COUNt) and trigger count (TRIGger:COUNt) are set from the Trigger Subsystem.*

When memory is initialized (:SYSTem:MEMory:INITialize), all 100 memory locations for a memory sweep are initialized to the present setup configuration of the SourceMeter with CALC 1 disabled. User-defined math expressions are replaced with the "Power" math expression.

Error 809 "Source memory location revised" occurs when a memory sweep references an expression that no longer exists. The memory sweep is revised to disable CALC1.

In order to execute a memory sweep, the product of the arm count and trigger count should be at least the same as the number of points in the sweep.

Use the :FUNCtion:MODE command to select the MEMory function (see "Select function mode"). Arm count (ARM:COUNt) and trigger count (TRIGger:COUNt) are set from the Trigger Subsystem.

:SAVE <NRf>

:SOURce[1]:SAVE <NRf> Save setup in specified memory location

Parameters <NRf> = 1 to 100 Specify memory location

Description This command is used to save the present instrument setup in a memory location. Up to 100 setups can be saved. The following settings are saved in each source memory location:

SENSe[1]:FUNCtion:CONCurrent
SENSe[1]:FUNCtion:ON
SENSe[1]:FUNCtion:OFF
SENSe[1]:RESistance:MODE
SENSe[1]:RESistance:OCOMpensated
SENSe[1]:AVERage:STATe
SENSe[1]:AVERage:TCONtrol
SENSe[1]:AVERage:COUNt
SOURce[1]:FUNCtion:MODE
SOURce[1]:DELay
SOURce[1]:DELay:AUTO
Source Value, Range, Auto Range
Sense Protection, Range, Auto Range
SYSTem:FRSWitch
SYSTem:RSENse
CALCulate1:STATe
CALCulate1:MATH[:EXPRession]:NAME
CALCulate2:FEED
CALCulate2:NULL:OFFSet
CALCulate2:NULL:STATe
CALCulate2:LIMit[1]:STATe
CALCulate2:LIMit[1]:COMPliance:FAIL
CALCulate2:LIMit[1]:COMPliance:SOURce2
CALCulate2:LIMit2:STATe
CALCulate2:LIMit2:UPPer[:DATA]
CALCulate2:LIMit2:UPPer:SOURce2
CALCulate2:LIMit2:LOWer[:DATA]
CALCulate2:LIMit2:LOWer:SOURce2
CALCulate2:LIMit3:STATe
CALCulate2:LIMit3:UPPer[:DATA]
CALCulate2:LIMit3:UPPer:SOURce2
CALCulate2:LIMit3:LOWer[:DATA]
CALCulate2:LIMit3:LOWer:SOURce2
CALCulate2:CLIMits:PASS:SOURce2
CALCulate2:CLIMits:PASS:SMLocation

After saving the desired setups in consecutive memory locations (unless branching, see CALC2:CLIM:PASS:SML), use the :POINts command to specify how many sweep points to perform and the :STARt command to specify where to start from.

:POINts <NRf>

:SOURCe:MEMory:POINts <NRf> — Specify number of sweep points to execute

Parameters <NRf> = 1 to 100 — Number of sweep points

Description This command is used to specify the number of points for the sweep. For example, if you saved setups in memory locations 1 through 12 for a sweep, specify a 12-point sweep using this command.

:STARt <NRf>

:SOURCe:MEMory:STARt <NRf> — Select Source Memory Sweep start location

Parameters <NRf> = 1 to 100 — Specify memory location

Description This command is used to set the starting location of a Source Memory Sweep. For example, for setups saved in memory locations 98 through 5, specify a starting location of 98.

:RECall <NRf>

:SOURCe:MEMory:RECall <NRf> — Return to specified setup

Parameters <NRf> = 1 to 100 — Specify memory location

Description This command is used to return the SourceMeter to the setup stored at the specified memory location.

Sweep and list program examples

Linear voltage sweep

Linear voltage sweep from 1V to 10V in 1V increments:

```
*RST
SOUR:FUNC:MODE VOLT
SOUR:SWE:SPAC LIN
SOUR:VOLT:STAR 1.0
SOUR:VOLT:STOP 10.0
SOUR:VOLT:STEP 1.0
SOUR:SWE:POIN? (returns 10)
TRIG:COUN 10
SOUR:VOLT:MODE SWE
OUTP ON
INIT
```

Voltage list

The previous Linear Voltage Sweep can instead be performed using a Voltage List as follows:

```
*RST
SOUR:FUNC:MODE VOLT
SOUR:LIST:VOLT 1,2,3,4,5,6,7,8,9,10
SOUR:LIST:VOLT:POIN? (returns 10)
TRIG:COUN 10
SOUR:VOLT:MODE LIST
OUTP ON
INIT
```

Logarithmic current sweep

Logarithmic current sweep from 1mA to 270mA in 20 points:

```
*RST
SOUR:FUNC:MODE CURR
SOUR:SWE:SPAC LOG
SOUR:CURR:STAR .001
SOUR:VOLT:STOP .27
SOUR:SWE:POIN 20
TRIG:COUN 20
SOUR:CURR:MODE SWE
OUTP ON
INIT
```

To determine the source values that will be generated:

Start: .001 Log10(Start): -3
Stop: .270 Log10(Stop): -.5686

LogStep = (Log10(Stop) - Log10(Start)) / (SWE:POIN -1)
= (-.5676 - -3) / (20 - 1)
= .127966513

Now add the LogStep value to Log10(Start) and to each subsequent result. This will create a list of Log10 Values. Next take 10 raised to each Log10 Value to calculate the actual sweep values:

Value#	Log10 Value	Sweep Value
1	-3.000000	0.001000
2	-2.872033	0.001343
3	-2.744067	0.001803
4	-2.616100	0.002420
5	-2.488134	0.003250
6	-2.360167	0.004363
7	-2.232201	0.005859
8	-2.104234	0.007866
9	-1.976268	0.010562
10	-1.848301	0.014181
11	-1.720335	0.019040
12	-1.592368	0.025564
13	-1.464402	0.034324
14	-1.336435	0.046086
15	-1.208469	0.061877
16	-1.080502	0.083080
17	-0.952536	0.111549
18	-0.824569	0.149772
19	-0.696603	0.201093
20	-0.568636	0.270000

Current list

The Previous Log Current Sweep can instead be performed by using the sweep values in a Current List as follows:

```
*RST
SOUR:FUNC:MODE CURR
SOUR:LIST:CURR 0.001,0.001343,0.001803,0.002420,0.003250,0.004363,0.005859
SOUR:LIST:CURR:APP 0.007866,0.010562,0.01418,0.019040,0.025564,0.03424
SOUR:LIST:CURR:APP 0.046086,0.061877,0.083080,0.111549,0.149772,0.201093,0.27
SOUR:LIST:CURR:POIN? (returns 20)
TRIG:COUN 20
SOUR:CURR:MODE LIST
OUTP ON
INIT
```

SOURce2

The following commands are used to set the logic level of the digital output lines, and control the pulse width of limit test output patterns that are sent to component handlers. Limit tests are configured and controlled from the CALCulate2 Subsystem. For details on limit testing, see "Limit testing" in Section 3.

Setting digital output

[:LEVel] <NRf>

:SOURce:TTL:[LEVel] <NRf> — Set digital output pattern

Parameters <NRf> = 0 to 15 — Specify digital output value

Query :TTL? — Query digital output value

Description This command is used to set the logic levels of the four output lines of the Digital I/O port. When set high, the specified output line will be at approximately +5V. When set low, the output line will be at 0V.

Use the following table to determine the parameter value for the desired digital output pattern:

OUT 4	OUT 3	OUT 2	OUT 1	Value
L	L	L	L	0
L	L	L	H	1
L	L	H	L	2
L	L	H	H	3
L	H	L	L	4
L	H	L	H	5
L	H	H	L	6
L	H	H	H	7
H	L	L	L	8
H	L	L	H	9
H	L	H	L	10
H	L	H	H	11
H	H	L	L	12
H	H	L	H	13
H	H	H	L	14
H	H	H	H	15

L = Low (Gnd)
H = High (>+3V)

Clearing digital output

[:IMMediate]

:SOURce2:CLEar[:IMMediate] Clear digital output lines

Description This action command is used to immediately restore the digital output lines to the output pattern defined by the :TTL:LEVel command.

:AUTO <b>

:SOURce2:CLEar:AUTO <b> Control auto-clear for digital output

Parameters

<b> =	0 or OFF	Disable auto-clear
	1 or ON	Enable auto-clear

Query :AUTO? Query auto-clear

Description This command is used to enable or disable auto-clear for the digital output lines. When enabled, the output pattern will clear automatically after the "pass or fail" output bit pattern of a limit test is sent to a handler via the digital output lines.

The :DELay command (see next command) specifies the pulse width of the limit test bit pattern. After the delay period times out, the digital output clears back to the output pattern programmed by the :TTL:LEVel command.

When auto-clear is disabled, the digital output pattern can only be cleared by the :IMMediate command.

On power-up, auto clear is enabled.

See :CALCulate2 Subsystem and "Limit testing" in Section 2 for details on limit tests.

:DELay <n>

:SOURce2:CLEar:AUTO:DELay <n> — Set delay for auto-clear

Parameters

<n> =	0 to 60	Specify delay (in seconds)
	DEFault	100µsec delay
	MINimum	0 sec
	MAXimum	60 sec

Query

:DELay?	Query delay
:DELay? DEFault	Query *RST default delay
:DELay? MINimum	Query lowest allowable delay
:DELay? MAXimum	Query maximum allowable delay

Description

This command is used to set the delay for digital output auto-clear. This delay determines the pulse width of the limit test output pattern as required by the handler. After the delay, the output returns (clears) to the pattern programmed by the :TTL:LEVel command.

The delay actually defines the pulse width for line 4, which is used by category register component handlers as the EOT (end of test) strobe. The pulse width of the other three lines are 20µsec longer (10µsec before line 4 is toggled, and 10µsec after line 4 is cleared). Skewing the timing on line 4 provides "setup" and "hold" time for category register component handlers. See "Limit testing" in Section 3 for details on timing.

STATus subsystem

The STATus subsystem is used to control the status registers of the Model 2420. These registers and the overall status structure are explained in "Status structure." The commands in this subsystem are summarized in Table 5-9.

Read event registers

[:EVENt]?

:STATus:MEASurement[:EVENt]?	Read Measurement Event Register
:STATus:QUEStionable[:EVENt]?	Read Questionable Event Register
:STATus:OPERation[:EVENt]?	Read Operation Event Register

Description These query commands are used to read the contents of the status event registers. After sending one of these commands and addressing the Model 2420 to talk, a value is sent to the computer. The value indicates which bits in the appropriate register are set. The event registers are shown in Figures 5-3, 5-4, and 5-5. Note that reading an event register clears the bits in that register.

The response message can be returned as a binary, octal, decimal, or hexadecimal value. The value format is set from the :FORMat:SREGister command (see FORMat subsystem).

If a binary value is returned, the value itself indicates which bits are set. For example, for a binary value of 110110, bits B5, B4, B2, and B1 are set. Bits B3 and B0 are clear. For the other formats, convert the octal, decimal, or hexadecimal value to its binary equivalent.

Assume that bits B5, B4, B2, B1, and B0 of an event register are set. Response messages would look like this:

Format	Response message
Binary	#B110111
Octal	#Q67
Decimal	55
Hexadecimal	#H37

Figure 5-3
Measurement event register

Bit Position	B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
Event	—	Comp	OVP	OT	INT	—	BFL	BAV	ROF	RAV	LP	HL3	LL3	HL2	LL2	L1
Decimal Weighting	—	16384 (2^{14})	8192 (2^{13})	4096 (2^{12})	2048 (2^{11})	—	512 (2^{9})	256 (2^{8})	128 (2^{7})	64 (2^{6})	32 (2^{5})	16 (2^{4})	8 (2^{3})	4 (2^{2})	2 (2^{1})	1 (2^{0})
Value	—	0/1	0/1	0/1	0/1	—	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1

Value: 1 = Measurement Event Set
0 = Measurement Event Cleared

Events: COMP = Compliance
OVP = Over Voltage Protection
INT = Interlock
BFL = Buffer Full
BAV = Buffer Available
ROF = Reading Overflow
RAV = Reading Available
LP = Limits Pass
HL3 = High Limit 3 Fail
LL3 = Low Limit 3 Fail
HL2 - High Limit 2 Fail
LL2 = Low Limit 2 Fail
L1 = Limit 1 Fail

Figure 5-4
Questionable event register

Bit Position	B15	B14	B13 - B9	B8	B7 - B0
Event	—	Warn	—	Cal	—
Decimal Weighting	—	16384 (2^{14})	—	256 (2^{8})	—
Value	—	0/1	—	0/1	—

Value: 1 = Questionable Event Bit Set
0 = Questionable Event Bit Cleared

Events: Warn = Command Warning
Cal = Calibration Summary

Figure 5-5
Operation event register

Bit Position	B15 - B11	B10	B9 - B7	B6	B5	B4	B3	B2	B1	B0
Event	—	Idle	—	Arm	Trig	—	Swp	—	—	Cal
Decimal Weighting	—	1024 (2^{10})	—	64 (2^{6})	32 (2^{5})	—	8 (2^{3})	—	—	1 (2^{0})
Value	—	0/1	—	0/1	0/1	—	0/1	—	—	0/1

Value: 1 = Operation Event Set
0 = Operation Event Cleared

Events: Idle = In Idle
Arm = Waiting for Arm Event
Trig = Waiting for Trigger Event
Swp = Sweeping
Cal = Calibrating

Measurement Event Register

Bit B0, Limit 1 Fail (L1) — Set bit indicates that the Limit 1 test has failed.

Bit B1, Low Limit 2 Fail (LL2) — Set bit indicates that the Low Limit 2 test has failed.

Bit B2, High Limit 2 Fail (HL2) — Set bit indicates that the High Limit 2 test has failed.

Bit B3, Low Limit 3 (LL3) — Set bit indicates that the Low Limit 3 test has failed.

Bit B4, High Limit 3 (HL3) — Set bit indicates that the High Limit 3 test has failed.

Bit B5, Limits Pass (LP) — Set bit indicates that all limit tests passed.

Bit B6, Reading Available (RAV) — Set bit indicates that a reading was taken and processed.

Bit B7, Reading Overflow (ROF) — Set bit indicates that the volts or amps reading exceeds the measurement range of the instrument.

Bit B8, Buffer Available (BAV) — Set bit indicates that there are at least two readings in the trace buffer.

Bit B9, Buffer Full (BFL) — Set bit indicates that the trace buffer is full.

Bit B10 — Not used.

Bit B11, Interlock Asserted (Int) — Set bit indicates that the interlock line is at digital low (asserted). The source output can be turned on.

Bit B12, Over Temperature (OT) — Set bit indicates that an over temperature condition exists. The source output cannot be turned on.

Bit B13, Over Voltage Protection (OVP) — Set bit indicates that the source is being limited at the programmed limit level.

Bit B14, Compliance (Comp) — Set bit indicates that the source is in compliance.

Bit B15 — Not used.

Questionable Event Register

Bits B0 through B7 — Not used.

Bit B8, Calibration Summary (Cal) — Set bit indicates that an invalid calibration constant was detected during the power-up sequence. This error will clear after successful calibration of the instrument.

Bits B9 through B13 — Not used.

Bit B14, Command Warning (Warn) — Set bit indicates that a Signal Oriented Measurement Command parameter has been ignored.

Bit B15 — Not used.

NOTE *Whenever a questionable event occurs, the ERR annunciator will turn on. The annunciator will turn off when the questionable event clears.*

Operation Event Register

Bit B0, Calibrating (Cal) — Set bit indicates that the instrument is calibrating.

Bit B1 and B2 — Not used.

Bit B3, Sweeping (Swp) — Set bit indicates that the instrument is performing a sweep operation.

Bit B4 — Not used.

Bit B5, Waiting for Trigger (Trig) — Set bit indicates that the instrument is waiting in the trigger layer for a TLINK trigger event.

Bit B6, Waiting for Arm (Arm) — Set bit indicates that the instrument is waiting in the arm layer for an arm event.

Bits B7 through B9 — Not used.

Bit B10, Idle (Idle) — SourceMeter in idle state.

Bits B11 through B15 — Not used.

Program event enable registers

:ENABle <NDN> or <NRf>

:STATus:MEASurement:ENABle <NDN> or <NRf>	Program Measurement Event Enable Register
:STATus:QUEStionable:ENABle <NDN> or <NRf>	Program Questionable Event Enable Register
:STATus:OPERation:ENABle <NDN> or <NRf>	Program Operation Event Enable Register

Parameters

<NDN> =	#Bxx...x	Binary format (x = 1 or 0)
	#Qxx...x	Octal format (x = 0 through 7)
	#Hxx...x	Hexadecimal format (x = 0 through 9, A through F)
<NRf> =	0 to 65535	Decimal (ASCII) format
	where:	0 clears register 65535 sets all bits

Query

ENABle?	Query enable register

The format of the response message value (ASCII, binary, octal, or hexadecimal) depends on the presently selected format. Format is set from the :FORMat:SREGister command.

Description

These commands are used to set the contents of the event enable registers (see Figures 5-6, 5-7, and 5-8). An :ENABle command is sent with a parameter value that determines the desired state (0 or 1) of each bit in the appropriate register.

Figure 5-6
Measurement event enable register

Bit Position	B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
Event	—	Comp	OVP	OT	INT	—	BFL	BAV	ROF	RAV	LP	HL3	LL3	HL2	LL2	L1
Decimal Weighting	—	16384 (2^{14})	8192 (2^{13})	4096 (2^{12})	2048 (2^{11})	—	512 (2^{9})	256 (2^{8})	128 (2^{7})	64 (2^{6})	32 (2^{5})	16 (2^{4})	8 (2^{3})	4 (2^{2})	2 (2^{1})	1 (2^{0})
Value	—	0/1	0/1	0/1	0/1	—	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1

Value: 1 = Enable Measurement Event
0 = Disable (Mask) Measurement Event

Events: COMP = Compliance
OVP = Over Voltage Protection
INT = Interlock
BFL = Buffer Full
BAV = Buffer Available
ROF = Reading Overflow
RAV = Reading Available
LP = Limits Pass
HL3 = High Limit 3 Fail
LL3 = Low Limit 3 Fail
HL2 - High Limit 2 Fail
LL2 = Low Limit 2 Fail
L1 = Limit 1 Fail

Figure 5-7
Questionable event enable register

Bit Position	B15	B14	B13 - B9	B8	B7 - B0
Event	—	Warn	—	Cal	—
Decimal Weighting	—	16384 (2^{14})	—	256 (2^{8})	—
Value	—	0/1	—	0/1	—

Value: 1 = Enable Questionable Event
0 = Disable Questionable Event

Events: Warn = Command Warning
Cal = Calibration Summary

Figure 5-8
Operation event enable register

Bit Position	B15 - B11	B10	B9 - B7	B6	B5	B4	B3	B2	B1	B0
Event	—	Idle	—	Arm	Trig	—	Swp	—	—	Cal
Decimal Weighting	—	1024 (2^{10})	—	64 (2^{6})	32 (2^{5})	—	8 (2^{3})	—	—	1 (2^{0})
Value	—	0/1	—	0/1	0/1	—	0/1	—	—	0/1

Value: 1 = Enable Operation Event
0 = Disable (Mask) Operation Event

Events: Idle = In Idle
Arm = Waiting for Arm Event
Trig = Waiting for Trigger Event
Swp = Sweeping
Cal = Calibrating

Each event enable register is used as a mask for events (see [:EVENt] for descriptions of events). When a bit in an event enable register is cleared (0), the corresponding bit in the event register is masked and thus, cannot set the corresponding summary bit of the next register set in the status structure. Conversely, when a bit in an event enable register is set (1), the corresponding bit in the event register is unmasked. When the unmasked bit in the event register sets, the summary bit of the next register set in the status structure will set.

An enable register can be programmed using a binary, octal, decimal, or hexadecimal parameter value. As shown in "Parameters," the decimal format uses an <NRf> parameter type, and the other formats use an <NDN> type.

Use Figure 5-6, 5-7, or 5-8 to determine the parameter value for an enable command. For example, if you wish to set bits B4, B3, and B1 of an enable register, the binary value would be 11010 (where B4=1, B3=1, B2=0, B1=1, and B0=0). If you wish to use one of the other formats, convert the binary number to its octal, decimal, or hexadecimal equivalent.

Note that the decimal weight of each bit is included in the illustrations. To determine the decimal parameter value, add the decimal weights of each bit you wish to set. For binary 11010, the decimal equivalent is 26 (16+8+2).

The following examples show proper syntax for setting Bits B8, B3, and B1 of the Measurement Event Enable Register:

```
:stat:meas:enab #b100001010    (binary format, <NDN> parameter)
:stat:meas:enab #q412          (octal format, <NDN> parameter)
:stat:meas:enab #h10A          (hexadecimal format, <NDN> parameter)
:stat:meas:enab 266            (decimal format, <NRf> parameter)
```

Read condition registers

:CONDition?

```
:STATus:MEASurement:CONDition?      Read Measurement Condition
:STATus:QUEStionable:CONDition?     Read Questionable Register
:STATus:OPERation:CONDition?        Read Operation Condition
```

Description These query commands are used to read the contents of the condition registers. Each set of event registers (except the Standard Event register set) has a condition register. A condition register is similar to its corresponding event register, except that it is a real-time register that constantly updates to reflect the present operating status of the instrument. See [:EVENt]? for register bit descriptions.

After sending one of these commands and addressing the Model 2420 to talk, a value is sent to the computer. This value indicates which bits in the appropriate register are set.

The response message can be returned as a binary, octal, decimal, or hexadecimal value. The value format is set using the :FORMat:SREGister command (see FORMat subsystem).

If a binary value is returned, the value itself indicates which bits are set. For example, for a binary value of 110110, bits B5, B4, B2, and B1 are set. Bits B3 and B0 are clear. For the other formats, convert the octal, decimal, or hexadecimal value to its binary equivalent.

Assume that bits B5, B4, B2, B1, and B0 of an event register are set. Response messages would look like this:

Format	Response message
Binary	#B110111
Octal	#Q67
Decimal	55
Hexadecimal	#H37

Select default conditions

:PRESet

:STATus:PRESet — Return registers to default conditions

Description When this command is sent, the following SCPI event registers are cleared to zero (0):

1. Operation Event Enable Register.
2. Event Enable Register.
3. Measurement Event Enable Register.

NOTE *The Standard Event Register is not affected by this command.*

Error queue

[:NEXT]?

:STATus:QUEue[:NEXT]? — Read Error Queue

Description As error and status messages occur, they are placed into the Error Queue. This query command is used to read those messages.

The Error Queue is a first-in, first-out (FIFO) register. Every time you read the queue, the "oldest" message is read and that message is then removed from the queue. The queue will hold up to 10 messages. If the queue becomes full, the message "350, 'Queue Overflow'" will occupy the last memory location in the register. On power-up, the Error Queue is empty. When the Error Queue is empty, the message "0, 'No error'" is placed in the Error Queue.

The messages in the queue are preceded by a number. Negative (-) numbers are used for SCPI defined messages, and positive (+) numbers are used for Keithley defined messages. The messages are listed in Appendix B.

After this command is sent and the Model 2420 is addressed to talk, the "oldest" message in the queue is sent to the computer.

NOTE *The :STATus:QUEue[:NEXT]? query command performs the same function as the :SYSTem:ERRor? query command (see System subsystem).*

:CLEar

:STATus:QUEue:CLEar — Clear Error Queue

Description This action command is used to clear the Error Queue of messages.

ENABle <list>

:STATus:QUEue:ENABle <list> — Enable messages for Error Queue

Parameters <list> = (numlist)

where numlist is a specified list of messages that you wish to enable for the Error.

Query :ENABle? — Query list of enabled messages

Description On power-up, all error messages are enabled and will go into the Error Queue as they occur. Status messages are not enabled and will not go into the queue. This command is used to specify which messages you want enabled. Messages not specified will be disabled and prevented from entering the queue.

When this command is sent, all messages will first be disabled, then the messages specified in the list will be enabled. Thus, the returned list (:ENABle?) will contain all the enabled messages.

Messages are specified by numbers (see Appendix B). The following examples show various forms for expressing a message numlist:

numlist =	-110	Single message.
	-110:-222	Range of messages (-100 through 222).
	-110:-222, -230	Range entry and single entry by a comma.

NOTE *To disable all messages from entering the Error Queue, send the following command:*

:stat:que:enab ()

DISable <list>

:STATus:QUEue:DISable <list> Disable messages for Error Queue

Parameters <list> = (numlist)

where numlist is a specified list of messages that you wish to disable for the Error Queue.

Query :DISable? Query list of disabled messages

On power-up, all error messages are enabled and will go into the Error Queue as they occur. Status messages are not enabled and will not go into the queue. This command is used to specify which messages you want disabled. Disabled messages are prevented from going into the Error Queue.

Messages are specified by numbers (see Appendix B). See :QUEue:ENABle for examples to express a numlist.

:SYSTem subsystem

The SYSTem subsystem contains miscellaneous commands that are summarized in Table 5-10.

Default conditions

:PRESet

:SYSTem:PRESet — Return to :SYSTem:PRESet defaults

Description This command returns the instrument to states optimized for front panel operation. :SYSTem:PRESet defaults are listed in the SCPI tables (Tables 5-2 through 5-12).

:POSetup

:SYSTem:POSetup <name> — Program power-on defaults

Parameters

<name> =	RST	Power-up to *RST defaults
	PRESet	Power-up to :SYSTem:PRESet defaults
	SAV0	Power-up to setup stored at memory location 0
	SAV1	Power-up to setup stored at memory location 1
	SAV2	Power-up to setup stored at memory location 2
	SAV3	Power-up to setup stored at memory location 3
	SAV4	Power-up to setup stored at memory location 4

Query :POSetup? — Query power-on setup

Description This command is used to select the power-on defaults. With RST selected, the instrument powers up to the *RST default conditions. With PRES selected, the instrument powers up to the :SYStem:PRESet default conditions. Default conditions are listed in the SCPI tables (Tables 5-2 through 5-11).

With the SAV0-4 parameters specified, the instrument powers-on to the setup that is saved in the specified location using the *SAV command.

Select input jacks

:FRSWitch <name>

:SYSTem:FRSWitch <name> — Select front or rear panel in/out jacks

Parameters

<name> =	FRONt	Front panel in/out jacks
	REAR	Rear panel in/out jacks

Query :FRSWitch? — Query state of front/rear switch setting

Description This command is used to select which set of in/out terminals to enable (front panel or rear panel).

NOTE: For SCPI compatibility, use the :ROUTe:TERMinals command to select in/out jacks.

Control remote sensing

:RSENse <b>

:SYSTem:RSENse <b> Enable or disable remote sensing.

Parameters <b> = 0 or OFF Disable remote sensing
1 or ON Enable remote sensing

Query :RSENse? Query state of remote sensing

Description This command is used to enable or disable remote sensing. When using remote sensing, 4-wire connections to the DUT are required.

Sourcing voltage — With remote sensing enabled, the output voltage is sensed (measured) at the DUT. If the sensed voltage is lower than the programmed amplitude, then the V-Source increases the voltage until the sensed voltage is the same as the programmed amplitude. This compensates for IR drop in the OUTPUT test leads.

With remote sensing disabled, the output voltage is sensed at the output connectors.

Measuring voltage — With remote sensing enabled, voltage measurements are made at DUT. This eliminates any voltage drops that may be in the test leads between the Model 2420 and the DUT.

With remote sensing disabled, voltage measurements are performed at the output connectors of the instrument.

Measuring resistance — With remote sensing enabled, 4-wire resistance measurements can be made.

NOTE *See "Basic circuit configurations" and "Connections to DUT" in Section 2 for details on sensing.*

Select guard mode

:GUARd <name>

:SYSTem:GUARd <name> Select guard mode

Parameters <name> = OHMS Ohms guard mode
CABLe Cable guard mode

Query :GUARd? Query guard mode

Description This command is used to select the guard mode. OHMS guard is a low-impedance guard drive used for in-circuit resistance measurements. Ohms guard is not available for the 1kV and 1A ranges (source or measure). CABLE guard provides a high-impedance guard drive that is used to eliminate leakage currents in cabling and test fixtures.

When performing 6-wire ohms guard measurements, use the GUARD output state. The OUTPut [1]:SMODe GUARd command is used to select the GUARD output-off state. For details on the GUARD output-off state, see "Configure output" in Section 2.

NOTE *See "Basic circuit configurations" and "Connections to DUT" in Section 2 for details on guarding.*

Reset timestamp

:RESet

:SYSTem:TIME:RESet — Reset timestamp

Description This action command is used to reset the absolute timestamp to 0 seconds. The timestamp also resets to 0 seconds every time the SourceMeter is turned on.

Initialize memory

:INITialize

:SYSTem:MEMory:INITialize — Initializes battery backed RAM

Description When this command is used, the following actions to initialize battery backed RAM occur:

- TRACe (data store) data is lost, buffer size is reset to 100, and timestamp is set to the absolute format.
- SOURce1:LIST:CURR and VOLT are reset to 0A and 0V, respectively.
- Deletes all user-defined math expressions (see CALCulate1 Subsystem).
- All 100 memory locations for a memory sweep are initialized to the present setup configuration of the SourceMeter with CALC 1 disabled. User-defined math expressions are replaced with the "Power" math expression.
- The four standard save setups (*SAV0 - *SAV4) are initialized to the present setup configuration of the SourceMeter.
- All CALCulate1 user-defined math expressions are deleted.

Cooling fan (output off)

:FCONtrol <name>

:SYSTem:FCONtrol <name> — Select fan speed for output off

Parameters

<name> =	ALWays	Speed is range-dependent
	OUTPut	Low speed

Query :FCONtrol? — Query fan speed selection

Description This command is used to set the cooling fan speed when the output is off. With OUTPut selected, the fan will run at the low speed (50%) when the output is turned off. With ALWays selected, the fan speed will be range-dependent.

On the 10µA, 100µA, and 1mA ranges, the fan runs at the low speed (50%). On the 10mA and 100mA ranges, the fan runs at the medium speed (75%). On the 1A and 3A ranges, the fan runs at the high speed (100%).

NOTE: With the output on, cooling fan speed is always range-dependent.

Control beeper

[:IMMediate] <freq, time>

:SYSTem:BEEPer[:IMMediate] <freq, time>

Parameters

freq =	65 to 2e6	Specify frequency in Hz
time =	0 to 7.9	Specify time duration

NOTE *The frequency and time values must be separated by a comma (i.e., :syst:beep 100, 3).*

Description The beeper of the SourceMeter can be used to provide an audible signal at a specified frequency and time duration (up to 7.9 seconds @ 65Hz). This beeper can, for example, be used to signal the end a lengthy sweep.

Example: :SYSTem:BEEPer 500, 1 Beep at 500Hz for 1 second

The correlation between the duration and frequency of the beep is expressed as follows:

Maximum Time = 512/ Frequency

For example, at a frequency of 512Hz, the maximum beep time is one second. You can set the time greater than one (1) second, but it will only beep for one second.

Note that in order to use this command, the beeper must be enabled (see next command).

:STATe <b>

:SYSTem:BEEPer:STATe <b> Enable or disable beeper

Parameters

<b> =	1 or ON	Enable beeper
	0 or OFF	Disable beeper

Query :STATe? Query state of beeper

Description This command is used to enable or disable the beeper. When enabled, a short beep is provided to signal that a front panel key has been pressed.

Control autozero

:STATe <b>

:SYSTem:AZERo:STATe <b> Control autozero

Parameters

<b> =	1 or ON	Enable autozero
	0 or OFF	Disable autozero

Query :STATe? Query state of autozero

Description This command is used to disable or enable autozero. When enabled, accuracy is optimized. When disabled, speed is increased at the expense of accuracy.

Select power line frequency setting

:LFRequency <freq>

:SYSTem:LFRequency <freq> — Select line frequency

Parameters <freq> = 50 — 50Hz or 400Hz setting
60 — 60Hz setting

Query :LFRequency? — Query line frequency selection.

Description Use this command to manually select the line frequency setting (50 or 60Hz). For 400Hz operation, select 50Hz.

:AUTO <b>

:SYSTem:LFRequency:AUTO <b> — Control auto line frequency selection

Parameters <b> = 1 or ON — Enable and line frequency selection
0 or OFF — Disable auto line frequency selection

Query :AUTO? — Query state of auto line frequency selection.

Description This command is used to enable or disable auto line frequency detection. When enabled, the SourceMeter will sense the line frequency on power-up and select the appropriate line frequency setting.

Manually setting the line frequency (see previous command) disables auto frequency.

Error queue

[:NEXT]?

:SYSTem:ERRor[:NEXT]? — Read oldest error (code and message)

Description As error and status messages occur, they are placed in the Error Queue. The Error Queue is a first-in, first-out (FIFO) register that can hold up to 10 messages. After sending this command and addressing the Model 2420 to talk, the oldest message is sent to the computer and is then removed from the queue.

A code number, which precedes the message, is also sent. Negative (-) numbers are used for SCPI defined messages, and positive (+) numbers are used for Keithley defined messages. Appendix B lists the messages.

If the queue becomes full, the "350, Queue Overflow" message occupies the last memory location in the register. On power-up, the queue is empty. When empty, the "0, No error" message is placed in the Error Queue.

NOTE: The :STATus:Queue? command performs the same function as :SYSTem:ERRor[:NEXT]? (see STATus subsystem).

:ALL?

:SYSTem:ERRor:ALL? Read all errors (codes and messages)

Description This query command is similar to the [:NEXT]? command except that all messages in the Error Queue are sent to the computer when the Model 2420 is addressed to talk. All messages are removed from the queue.

:COUNt?

:SYSTem:ERRor:COUNt? Return the number of errors

Description After sending this command and addressing the Model 2420 to talk, a decimal number will be sent to the computer. That is the number of messages in the Error Queue.

:CODE[:NEXT]?

:SYSTem:ERRor:CODE[:NEXT]? Read oldest error (code only)

Description This command is identical to the [:NEXT]? command, except only the code is returned. The message itself is not returned. The error is cleared from the queue.

:CODE:ALL?

SYSTem:ERRor:CODE:ALL? Read all errors (codes only)

Description This query command is identical to the :ALL? command, except only the codes are returned. The actual messages are not returned. All errors are cleared from the queue.

:CLEar

:SYSTem:CLEar Clear Error Queue

Description This action command is used to clear the Error Queue of messages.

Simulate key presses

:KEY

:SYSTem:KEY <NRf> Simulate key-press

Parameters

<NRf> =	
1	RANGE up arrow key
2	SOURCE down arrow key
3	left arrow key
4	MENU key
5	FCTN key
6	FILTER key
7	SPEED key
8	EDIT key
9	AUTO key
10	right arrow key
11	EXIT key
12	V (SOURCE) key
13	LIMITS key
14	STORE key
15	V (MEAS) key
16	TOGGLE key
17	RANGE down arrow key
18	ENTER key
19	I (SOURCE) key
20	TRIG key
21	RECALL key
22	I (MEAS) key
23	LOCAL key
24	ON/OFF key
25	-----
26	SOURCE up arrow key
27	SWEEP key
28	CONFIG key
29	Ω key
30	REL key
31	DIGITS key
32	FRONT/REAR key

Query :KEY? Query last "pressed" key.

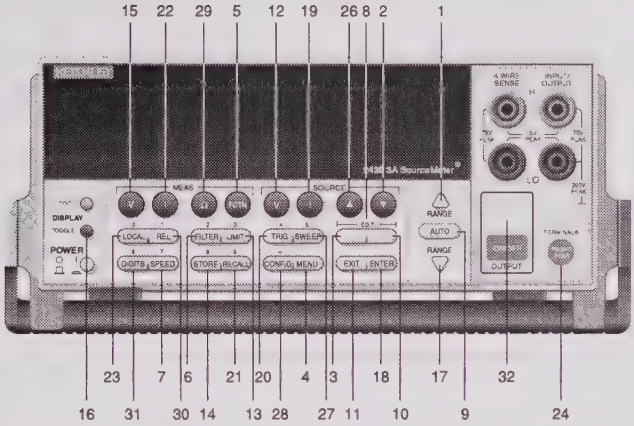
Description This command is used to simulate front panel key presses. For example, to select the voltage measurement function (V), you can send the following command to simulate pressing the V (MEAS) key:

```
:syst:key 15
```

The parameter listing provides the key-press code in numeric order. Figure 5-9 also illustrates the key-press codes.

The queue for the :KEY? query command can only hold one key-press. When :KEY? is sent over the bus, and the Model 2420 is addressed to talk, the key-press code number for the last key pressed (either physically or with :KEY) is sent to the computer.

Figure 5-9
Key-press codes



Parameters

<NRf>
1 RANGE up arrow key
2 SOURCE down arrow key
3 left arrow key
4 MENU key
5 FCTN key
6 FILTER key
7 SPEED key
8 EDIT key
9 AUTO key
10 right arrow key
11 EXIT key
12 V (SOURCE) key
13 LIMITS key
14 STORE key
15 V (MEAS) key
16 TOGGLE key
17 RANGE down arrow key
18 ENTER key
19 I (SOURCE) key
20 TRIG key
21 RECALL key
22 I (MEAS) key
23 LOCAL key
24 ON/OFF key
25 - (not used)
26 SOURCE up arrow key
27 SWEEP key
28 CONFIG key
29 Ω key
30 REL key
31 DIGITS key
32 FRONT/REAR key

Read version of SCPI standard

:VERSion?

:SYSTem:VERSion? Read SCPI version

Description This query command is used to read the version of the SCPI standard being used by the Model 2420. Example code:

1996.0

The above response message indicates the version of the SCPI standard.

RS-232 interface

:LOCal

:SYSTem:LOCal — Take 2420 out of remote

Description Normally, during RS-232 communications, front panel keys are operational. However, the user may wish to lock out front panel keys during RS-232 communications (see :RWLock).

This action command is used to take the Model 2420 out of the remote state and enables the operation of front panel keys. Note that this command can only be sent over the RS-232 interface.

:REMote

:SYSTem:REMote — Place the Model 2420 in remote

Description This action command is used to place the Model 2420 in the remote state. In remote, the front panel keys will be locked out if local lockout is asserted (see :RWLock). Note that this command can only be sent over the RS-232 interface.

:RWLock <b>

:SYSTem:RWLock <b> — Disable or enable front panel keys

Parameters

<b> =	0 or OFF	Disable local lockout
	1 or ON	Enable local lockout

Query :RWLock — Query state of local lockout

Description This command is used to enable or disable local lockout. When enabled, the front panel keys are locked out (not operational) when the instrument is in remote (see :REMote). When disabled, the front panel keys are operational in remote.

Taking the instrument out of remote (see :LOCal) restores front panel keys operation but does not change the status of the :RWLock command

Note that this command can only be sent over the RS-232 interface.

:TRACe subsystem

The commands in this subsystem are used to configure and control data storage into the buffer. The commands are summarized in Table 5-11.

:TRACe|:DATA

The bar (|) indicates that :TRACe or :DATA can be used as the root command for this subsystem. From this point on, the documentation in this manual uses :TRACe. If you prefer to use :DATA, simply replace all the :TRACe command words with :DATA.

Read and clear buffer

:DATA?

:TRACe:DATA? Read contents of buffer

Description When this command is sent and the Model 2420 is addressed to talk, all the readings stored in the data store sent to the computer.

The format that readings are sent over the bus is controlled from the :FORMat subsystem.

NOTE *See "Data flow" in Appendix D for a detailed explanation on how data flows through the various operation blocks of the SourceMeter. It clarifies the types of readings that are acquired by the various commands to read data.*

:CLEar

:TRACe:CLEar Clear buffer

Description This action command is used to clear the buffer of readings. If you do not clear the buffer, a subsequent store will overwrite the old readings.

Configure and control buffer

:FREE?

:TRACe:FREE? Read status of memory

Description This command is used to read the status of storage memory. After sending this command and addressing the Model 2420 to talk, two values separated by commas are sent to the computer. The first value indicates how many bytes of memory are available, and the second value indicates how many bytes are reserved to store readings.

:POINts <n>

:TRACe:POINts <n> — Specify buffer size

Parameters

<n> =	1 to 2500	Specify buffer size
	MINimum	1
	MAXimum	2500
	DEFault	100

Query

:POINts?	Query buffer size
:POINts? MINimum	Query smallest allowable buffer size
:POINts? MAXimum	Query largest allowable buffer size
:POINts? DEFault	Query *RST default buffer size

Description This command is used to specify the size of the buffer.

:ACTual?

:TRACe:POINts:ACTual? — Query number of stored readings

Description This query command is used to determine how many stored readings are in the buffer. After sending this command and addressing the unit to talk, the number of readings stored in the buffer will be sent to the computer.

:FEED <name>

:TRACe:FEED <name> — Specify readings source

Parameters

<name> =	SENSe[1]	Put raw readings in buffer
	CALCulate[1]	Put Calc1 readings in buffer
	CALCulate2	Put Calc2 readings in buffer

Query :FEED? Query buffer feed

Description This command is used to select the source of readings to be placed in the buffer. With SENSe[1] selected, raw readings are placed in the buffer when storage is performed.

With CALCulate[1] selected, math expression results (Calc1)) are placed in the buffer. With CALCulate2 selected, Calc2 readings are placed in the buffer.

NOTE: *Buffer feed cannot be changed while buffer storage is active.*

:CONTrol <name>

:TRACe:FEED:CONTrol <name> Start or stop buffer

Parameters

<name> =		
	NEXT	Fills buffer and stops
	NEVer	Disables buffer storage

Query :CONTrol? Query buffer control

Description This command is used to select the buffer control. When NEXT is selected, the asterisk (*) annunciator turns on to indicate that the buffer is enabled. The storage process starts when SourceMeter is taken out of idle to perform source-measure operations.

After the buffer stores the specified number of reading arrays (as set by the :POINTs command), the asterisk annuciators turns off to indicate that storage is done.

With NEVer selected, storage into the buffer is disabled.

Select timestamp format

:FORMat <name>

:TRACe:TSTamp:FORMat <name> Select timestamp format

Parameters

<name> =		
	ABSolute	Reference to first buffer reading
	DELTa	Time between buffer readings

Query :FORMat? Query timestamp format

Description This command is used to select the timestamp format for buffer readings. With ABSolute selected, each timestamp is referenced to the first reading stored in the buffer. With DELTa selected, timestamps provide the time between each buffer reading.

Trigger subsystem

The Trigger subsystem is made up of a series of commands and subsystems to configure the Trigger Model. These commands and subsystems are summarized in Table 5-12.

Initiate source/measure cycle

[:IMMediate]

:INITiate[:IMMediate] — Take 2420 out of idle state

Description This command is used to initiate source-measure operation by taking the Model 2420 out of idle. The :READ? and :MEASure? commands also perform an initiation.

Note that if auto output-off is disabled (SOURce1:CLEar:AUTO OFF), the source output must first be turned on before an initiation can be performed. The :MEASure? command automatically turns the output source on before performing the initiation.

WARNING **With auto output-off disabled, the source output will remain on after all programmed source-measure operations are completed. Beware of hazardous voltage that may be present on the output terminals.**

With auto output-off enabled, an initiation will start operation immediately. The source output will automatically turn on at the beginning of each SDM (source-delay-measure) cycle and turn off after each measurement is completed.

Abort source/measure cycle

:ABORt

Abort operation

Description When this action command is sent, the Model 2420 aborts operation and returns to the idle state.

A faster way to return to idle is to use the DCL or SDC command.

With auto output-off enabled (:SOURce1:CLEar:AUTO ON), the output will remain on if operation is terminated before the output has a chance to automatically turn off.

Program trigger model

:COUNt <n>

:ARM[:SEQuence[1]][LAYer[1]]:COUNt <n> — Set arm count
:TRIGger[:SEQuence[1]]:COUNt <n> — Set trigger count

Parameters

<n> =	1 to 2500	Specify count (see NOTE)
	DEFault	Sets count to 1
	MINimum	Sets count to 1
	MAXimum	See NOTE

NOTE The product of arm count and trigger count cannot exceed 2500.

Query

:COUNt?	Queries programmed count
:COUNt? DEFault	Queries *RST default count
:COUNt? MINimum	Queries lowest allowable count
:COUNt? MAXimum	Queries largest allowable count

Description This command is used to specify how many times an operation is performed in the specified layer of the trigger model.

For example, assume the arm count is set to 2 and the trigger counter is set to 10. This configures the SourceMeter to perform 10 source-measure operations twice for a total of 20 source-measure operations.

The product of the arm count and trigger count cannot exceed 2500. If, for example, the arm count is 2, then the maximum trigger count is 1250.

: DELay <n>

:TRIGger[:SEQuence[1]]:DELay <n> — Set trigger layer delay

Parameters

<n> =	0 to 999.9999	Specify delay in seconds
	DEFault	0 second delay
	MINimum	0 second delay
	MAXimum	999.9999 second delay

Query

:DELay?	Query the programmed delay
:DELay? DEFault	Query the *RST default delay
:DELay? MINimum	Query the lowest allowable delay
:DELay? MAXimum	Query the largest allowable delay

Description The delay is used to delay operation in the trigger layer. After the programmed trigger event occurs, the instrument waits until the delay period expires before performing the Device Action.

:SOURce <name>

:ARM[:SEQuence[1]][LAYer[1]]:COUNt <n> — Specify arm event control source
:TRIGger[:SEQuence[1]]:SOURce <name> — Specify trigger event control source

Parameters

<name> =	IMMediate	Pass operation through immediately
	TLINk	Select Trigger Link trigger as event
	TIMer	Select timer as event
	MANual	Select manual event
	BUS	Select bus trigger as event
	STESt	Select SOT pulse as event

NOTE Only IMMediate and TLINk are available as trigger layer control sources.

Query :SOURce? Query programmed control source.

Description These commands are used to select the event control source. With IMMediate selected operation immediately continues.

A specific event can be used to control operation. With TLINk selected, operation continues when a trigger pulse is received via the Trigger Link.

NOTE *The following control sources are not available for the trigger layer.*

With TIMer selected, the event occurs at the beginning of the timer interval, and every time it times out. For example, if the timer is programmed for a 30 second interval, the first pass through the control source occurs immediately. Subsequent arm events will then occur every 30 seconds. The interval for the timer is set using the :TIMer command.

With MANual selected, the event occurs when the TRIG key is pressed.

With BUS selected, the event occurs when a GET or *TRG command is sent over the bus.

With STESt selected, the event occurs when the SOT (start of test) pulse is received from a component handler via the Digital I/O port. This is used for limit testing.

:TIMer <n>

:ARM[:SEQuence[1]][:LAYer[1]]:TIMer <n> Set interval for arm layer timer

Parameters <n> = 0.000 to 9999.999 Specify timer interval in seconds
10000.00 to 99999.99 Specify timer interval in seconds

Query :TIMer? Query programmed timer interval

Description These commands are used to set the interval for the timer. Note that the timer is in effect only if the timer is the selected control source.

:DIRection <name>

:ARM[:SEQuence[1]][LAYer[1]][:TCONfigure]:DIRection <name> Control arm bypass
:TRIGger[:SEQuence[1]][:TCONfigure]:DIRection <name> Control trigger bypass

Parameters <name> = SOURc Enable control source bypass
ACCeptor Disable control source bypass

Query :DIRection? Query state of bypass

Description This command is used to enable (SOURce) or disable (ACCeptor) control source bypass. When enabled, operation will loop around the control source on the first pass in the layer. After that, repeat passes in the layer are held up and will wait for the programmed control source event.

:ILINe <NRf>

:ARM[:SEQuence[1]][LAYer[1]][:TCONfigure]:ILINe <NRf> Select input line; arm layer
:TRIGger[:SEQuence[1]][:TCONfigure]:ILINe <NRf> Select input line; trigger layer

Parameters

<NRf> =	1	Line #1
	2	Line #2
	3	Line #3
	4	Line #4

Query :ILINe? Query input trigger line

Description This command is used to select input lines for the Trigger Link. For normal operation, Trigger Link input and output (see :OLINe) should not share the same line.

:OLINe <NRf>

:ARM[:SEQuence[1]][LAYer[1]][:TCONfigure]:OLINe <NRf> Select output line; arm layer
:TRIGger[:SEQuence[1]][:TCONfigure]:OLINe <NRf> Select output line; trigger layer

Parameters

<NRf> =	1	Line #1
	2	Line #2
	3	Line #3
	4	Line #4

Query :OLINe? Query output trigger line

Description This command is used to select output lines for the Trigger Link. For normal operation, Trigger Link input and output (see :ILINe) should not share the same line.

OUTPut <event list>

:ARM[:SEQuence[1]][LAYer[1]][:TCONfigure]:OUTPut <event list> Arm layer event
:TRIGger[:SEQuence[1]][:TCONfigure]:OUTPut <event list> Trigger layer events

Parameters

Arm Layer Trigger

<event list >:	SWEep	Output trigger after a sweep
	NONE	Disable arm layer trigger

Trigger Layer Triggers

<event list >:	SOURce	Output trigger after source level is set
	DELay	Output trigger after delay period
	SENSe	Output Trigger after measurement
	NONE	Disable trigger layer triggers

NOTE *Each event in the list must be separated by a comma. (i.e., :arm:output source, delay, sense).*

Query :OUTPut? Query output trigger event(s)

Description This command is used to specify when trigger pulses occur on the specified output trigger line of the Trigger Link (see :OLINe).

Arm Layer Trigger — With SWEep selected, an output trigger will occur at the end of a sweep. With NONE selected, the arm layer trigger is disabled.

Trigger Layer Triggers — You can specify from one to all three events. Each event in the list must be separated by a comma (,).

The SOURce, DELay and MEASure events refer to the Source-Delay-Measure (SDM) cycle. This is the Device Action in the Trigger Model (see Figures 4-10 and 4-11). With SOURce specified, an output trigger occurs after the source is set. With DELay specified, an output trigger occurs after the delay period. With MEASure specified, an output trigger occurs after the measurement.

NOTE *When disabling triggers, the NONE parameter must sent alone (i.e., trig:outp none). If it is listed with any of the other event parameters, NONE will be ignored.*

A
Specifications

SOURCE SPECIFICATIONS[1]

Voltage Programming Accuracy (remote sense)

Range	Programming Resolution	Accuracy (1 Year) 23°C ±5°C ±% rdg. + volts	Noise (peak-peak) 0.1Hz – 10Hz
200.000 mV	5 µV	0.02% + 600 µV	10 µV
2.00000 V	50 µV	0.02% + 600 µV	50 µV
20.0000 V	500 µV	0.02% + 2.4 mV	500 µV
60.0000 V	1.5mV	0.02% + 7.2 mV	1500 µV

TEMPERATURE COEFFICIENT (0°–18°C & 28°–50°C): ±(0.15 × accuracy specification)/°C.

MAX. OUTPUT POWER: 66W (four quadrant source or sink operation).

SOURCE/SINK LIMITS: 5% over nominal for current and voltage.

VOLTAGE REGULATION: Line: 0.01% of range. **Load:** 0.01% of range + 100µV.

NOISE 10Hz–1MHz (p-p): 15mV maximum, resistive load.

OVER VOLTAGE PROTECTION: User selectable values, 5% tolerance. Factory default = 36 volts.

CURRENT LIMIT: Bipolar current limit (compliance) set with single value. Min. 0.1% of range.

OVERSHOOT: <0.1% typical (full scale step, resistive load, 10mA range).

Current Programming Accuracy (local or remote sense)

Range	Programming Resolution	Accuracy (1 Year) 23°C ±5°C ±% rdg. +amps	Noise (peak-peak) 0.1Hz – 10Hz
10.0000 µA	500 pA	0.033% + 2 nA	50 pA
100.000 µA	5 nA	0.031% + 20 nA	500 pA
1.00000 mA	50 nA	0.034% + 200 nA	5 nA
10.0000 mA	500 nA	0.045% + 2 µA	50 nA
100.000 mA	5 µA	0.066% + 20 µA	500 nA
1.00000 A[2]	50 µA	0.067% + 900 µA	50 µA
3.00000 A[2]	150 µA	0.059% + 2.7mA	150 µA

TEMPERATURE COEFFICIENT (0°–18°C & 28°–50°C): ±(0.15 × accuracy specification)/°C.

MAX. OUTPUT POWER: 66W (four quadrant source or sink operation).[2]

SOURCE/SINK LIMITS: ±1.05A @ 63V, ±3.15A @ 21V.

CURRENT REGULATION: Line: 0.01% of range. **Load:** 0.01% of range + 100pA.

VOLTAGE LIMIT: Bipolar voltage limit (compliance) set with single value. Min. 0.1% of range.

OVERSHOOT: <0.1% typical (1mA step, R_L = 10kΩ, 20V range).

[1] Specifications valid for continuous output currents below 105mA. For operating above 105mA on the 1A range for >1 minute, derate accuracy 10%/100mA above 105mA. For operating above 105mA on the 3A range for >1 minute, derate accuracy 10%/300mA above 105mA.

[2] Full power source operation regardless of load to 30°C. Above 30°C and/or power sink operation, refer to the Power Equations section of the User's Manual.

ADDITIONAL SOURCE SPECIFICATIONS

TRANSIENT RESPONSE TIME: 30µs typical for the output to recover to its spec. following a step change in load. Resistive load.

COMMAND PROCESSING TIME: Maximum time required for the output to begin to change following the receipt of :SOURce:VOLTage|CURRent <nrf> command. **Autorange On:** 10ms. **Autorange Off:** 7ms.

OUTPUT SETTLING TIME: Time required to reach 0.1% of final value after command is processed. 100µs typical. Resistive load. 10µA to 100mA range.

OUTPUT SLEW RATE: 0.14V/µs, 60V range, 100mA compliance. 0.08V/µs, 2V, and 20V ranges, 100mA compliance.

COMMON MODE VOLTAGE: 250VDC.

REMOTE SENSE: Up to 1V drop per load lead.

COMPLIANCE ACCURACY: For Source mode, add 0.1% of range to base specification. For Sink mode, 10µA to 100mA range, accuracy is ±(0.5% + offset*3). For Sink mode, 1A and 3A ranges, accuracy is ±(1.5% + offset*3).

OVER TEMPERATURE PROTECTION: Internally sensed temperature overload puts unit in standby mode.

RANGE CHANGE OVERSHOOT: Overshoot into a fully resistive 100kΩ load, 10Hz to 1MHz BW, adjacent ranges: (100mV) typical, except 20V/60V range boundary.

MINIMUM COMPLIANCE VALUE: 0.1% of range.

MEASURE SPECIFICATIONS [1, 2]

Voltage Measurement Accuracy (remote sense)

Range	Max. Resolution	Input Resistance	Accuracy (23°C ± 5°C) 1 Year, ±(%rdg + volts)
200.000 mV	1 µV	>10GΩ	0.012% + 300 µV
2.00000 V	10 µV	>10GΩ	0.012% + 300 µV
20.0000 V	100 µV	>10GΩ	0.015% + 1 mV
60.0000 V	300 µV	>10GΩ	0.015% + 3 mV

TEMPERATURE COEFFICIENT (0°–18°C & 28°–50°C): ±(0.15 × accuracy specification)/°C.

Current Measurement Accuracy (local or remote sense)

Range	Max. Resolution	Voltage Burden [3]	Accuracy (23°C ± 5°C) 1 Year, ±(%rdg + amps)
10.0000 µA	100 pA	< 1mV	0.027% + 700 pA
100.000 µA	1 nA	< 1mV	0.025% + 6 nA
1.00000 mA	10 nA	< 1mV	0.027% + 60 nA
10.0000 mA	100 nA	< 1mV	0.035% + 600 nA
100.000 mA	1 µA	< 1mV	0.055% + 6 µA
1.00000 A	10 µA	< 1mV	0.060% + 570 µA
3.00000 A	30 µA	< 1mV	0.052% + 1.71mA

TEMPERATURE COEFFICIENT (0°–18°C & 28°–50°C): ±(0.1 × accuracy specification)/°C.

Resistance Measurement Accuracy (4 wire remote sense)

Source I Mode, Auto Ohms

Range	Max. Resolution	Default Test Current	Normal Accuracy (23°C ± 5°C) 1 Year, ±(%rdg + ohms)	Enhanced Accuracy (23°C ± 5°C) [5] 1 Year, ±(%rdg + ohms)
<0.20000 Ω [4]	1 µΩ	—	Source I_{ACC} + Measure V_{ACC}	Measure I_{ACC} + Measure V_{ACC}
2.00000 Ω	10 µΩ	1 A	0.169% + 0.0003 Ω	0.129% + 0.0001 Ω
20.0000 Ω	100 µΩ	100 mA	0.098% + 0.003 Ω	0.073% + 0.001 Ω
200.000 Ω	1 mΩ	10 mA	0.077% + 0.03 Ω	0.053% + 0.01 Ω
2.00000 kΩ	10 mΩ	1 mA	0.066% + 0.3 Ω	0.045% + 0.1 Ω
20.0000 kΩ	100 mΩ	100 µA	0.063% + 3 Ω	0.043% + 1 Ω
200.000 kΩ	1 Ω	10 µA	0.065% + 30 Ω	0.046% + 10 Ω
2.00000 MΩ	10 Ω	10 µA	0.068% + 100 Ω	0.049% + 50 Ω
20.0000 MΩ	100 Ω	1 µA	0.249% + 1 kΩ	0.112% + 500 Ω
>20.0000 MΩ [4]	1 kΩ	—	Source I_{ACC} + Measure V_{ACC}	Measure I_{ACC} + Measure V_{ACC}

TEMPERATURE COEFFICIENT (0°–18°C & 28°–50°C): ±(0.15 × accuracy specification)/°C.

SOURCE I MODE, MANUAL OHMS: Total uncertainty = I source accuracy + V measure accuracy (4-wire remote sense).

SOURCE V MODE: Total uncertainty = V source accuracy + I measure accuracy (4-wire remote sense).

6-WIRE OHMS MODE: Available using active ohms guard and guard sense. **Max. Guard Output Current:** 50 mA (except 1A and 3A ranges). Accuracy is load dependent. Refer to manual for calculation formula.

GUARD OUTPUT IMPEDANCE: 0.1Ω in ohms mode.

[1] Speed = Normal (1 PLC).
[2] Accuracies apply to 2- or 4-wire mode when properly zeroed.
[3] 4-wire mode.
[4] Manual ohms mode only.
[5] Source readback enabled, offset compensation ON.

SYSTEM SPEEDS

MEASUREMENT[1]

MAXIMUM RANGE CHANGE RATE: 65/second.

MAXIMUM MEASURE AUTORANGE TIME: 40ms (fixed source)[2].

SWEEP OPERATION[3] READING RATES (rdg/second) FOR 60Hz (50Hz):

Speed	NPLC/Trigger Origin	Measure To Mem.	Measure To GPIB	Source-Measure To Mem.	Source-Measure To GPIB	Source-Measure Pass/Fail Test[4] To Mem.	Source-Measure Pass/Fail Test[4] To GPIB	Source-Memory[4] To Mem.	Source-Memory[4] To GPIB
Fast	0.01 / internal	2125(2010)	1000(1000)	1675 (1590)	900 (900)	1000 (990)	760(760)	200 (185)	200(185)
	0.01 / external	1250(1210)	910 (920)	1080 (1035)	830 (835)	940 (910)	710(710)	195 (180)	195(180)
Medium	0.10 / internal	510 (435)	510 (435)	475 (410)	475 (410)	400 (355)	400(355)	155 (140)	155(140)
	0.10 / external	435 (380)	435 (380)	415 (365)	415 (365)	390 (345)	390(345)	150 (135)	150(135)
Normal	1.00 / internal	59 (49)	59 (49)	58 (48)	58 (48)	57 (48)	57 (48)	46 (39)	46 (39)
	1.00 / external	57 (48)	57 (48)	57 (47)	57 (47)	56 (47)	56 (47)	46 (39)	46 (39)

SINGLE READING OPERATION READING RATES (rdg/second) FOR 60Hz (50Hz):

Speed	NPLC/Trigger Origin	Measure To GPIB	Source-Measure[5] To GPIB	Source-Measure Pass/Fail Test[4,5] To GPIB
Fast	0.01 / internal	200 (200)	65 (65)	65 (65)
Medium	0.10 / internal	160 (150)	60 (60)	60 (58)
Normal	1.00 / internal	46 (40)	31 (28)	30 (28)

COMPONENT HANDLER INTERFACE TIME: [4,6]

Speed	NPLC/Trigger Origin	Measure Pass/Fail Test	Source Pass/Fail Test	Source-Measure Pass/Fail Test[7]
Fast	0.01 / external	0.96 ms (1.07 ms)	0.5 ms (0.5 ms)	4.0 ms (4.0 ms)
Medium	0.10 / external	2.5 ms (2.8 ms)	0.5 ms (0.5 ms)	5.5 ms (5.75 ms)
Normal	1.00 / external	17.5 ms (20.85 ms)	0.5 ms (0.5 ms)	20.5 ms (24 ms)

[1] Reading rates applicable for voltage or current measurements. Auto zero off, autorange off, filter off, display off, trigger delay = 0, source auto clear off, and binary reading format.

[2] Purely resistive load. 10µA range <65ms.

[3] 1000 point sweep was characterized with the source on a fixed range.

[4] Pass/Fail test performed using one high limit and one low math limit.

[5] Includes time to re-program source to a new level before making measurement.

[6] Time from falling edge of START OF TEST signal to falling edge of END OF TEST signal.

[7] Command processing time of :SOURce:VOLTage|CURRent:TRIGgered <nrf> command not included.

GENERAL

NOISE REJECTION:

	NPLC	NMRR	CMRR
Fast	0.01	—	80 dB
Medium	0.1	—	80 dB
Normal	1	60 dB	120 dB [1]

LOAD IMPEDANCE: Stable into 20,000pF typical.

COMMON MODE VOLTAGE: 250VDC.

COMMON MODE ISOLATION: $>10^9\Omega$, <1000pF.

OVERRANGE: 105% of range, source and measure.

MAX. VOLTAGE DROP BETWEEN INPUT/OUTPUT AND SENSE TERMINALS: 5 volts.

MAX. SENSE LEAD RESISTANCE: 1MΩ for rated accuracy.

SENSE INPUT IMPEDANCE: $>10^{10}\Omega$.

GUARD OFFSET VOLTAGE: 300µV, typical.

SOURCE OUTPUT MODES:
Fixed DC level
Memory List (mixed function)
Stair (linear and log)

SOURCE MEMORY LIST: 100 points max.

MEMORY BUFFER: 5,000 readings @ 5½ digits (two 2,500 point buffers). Includes selected measured value(s) and time stamp. Lithium battery backup (3 yr+ battery life).

PROGRAMMABILITY: IEEE-488 (SCPI-1996.0), RS-232, 5 user-definable power-up states plus factory default and *RST.

DIGITAL INTERFACE:

Safety Interlock: Active low input.

Handler Interface: Start of test, end of test, 3 category bits. +5V @ 300mA supply.

Digital I/O: 1 trigger input, 4 TTL/Relay Drive outputs (33V @ 500mA sink, diode clamped).

POWER SUPPLY: 90V to 250V rms, 50–60Hz, 220VA.

COOLING: Forced air, variable speed.

WARRANTY: 1 year.

EMC: Conforms with European Union Directive 89/336/EEC EN 55011, EN 50082-1, EN 61000-3-2 and 61000-3-3, FCC part 15 class B.

SAFETY: Conforms with European Union Directive 73/23/EEC EN 61010-1, UL 3111-1.

VIBRATION: MIL-T-28800E Type III, Class 5.

WARM-UP: 1 hour to rated accuracies.

DIMENSIONS: 89mm high × 213mm wide × 370mm deep (3½in × 8⅜ in × 14⁹⁄₁₆ in). Bench Configuration (with handle & feet): 104mm high × 238mm wide × 370mm deep (4⅛ in × 9⅜ in × 14⁹⁄₁₆ in).

WEIGHT: 3.68kg (8.1 lbs).

ENVIRONMENT:

Operating: 0°–50°C, 70% R.H. up to 35°C. Derate 3% R.H./°C, 35°–50°C.

Storage: –25°C to 65°C.

[1] Except lowest current range = 90dB.

Specifications subject to change without notice.

Accuracy calculations

The information below discusses how to calculate accuracy for both sense and source functions.

Measure accuracy

Measurement accuracy is calculated as follows:

Accuracy = ±(% of reading + offset)

As an example of how to calculate the actual reading limits, assume that you are measuring 10V on the 20V range. You can compute the reading limit range from one-year measure voltage accuracy specifications as follows:

Accuracy = ±(% of reading + offset)
= ±[(0.015% × 10V) + 1.5mV]
= ±(1.5mV + 1.5mV)
= ±3mV

Thus, the actual reading range is 10V± 3mV or from 9.997 to 10.003V.

DC current measurement calculations are performed in exactly the same manner using the pertinent specifications, ranges, and input signal values.

Source accuracy

Source accuracy is calculated similarly, except source specifications are used. As an example of how to calculate the actual source output limits, assume that you are sourcing 0.7mA on the 1mA source range. You can compute the reading limit range from source current one-year accuracy specifications as follows:

Accuracy = ±(0.034% of output + 200nA offset)
= ±[(0.034% × 0.7mA) + 200nA)]
= ±(238nA + 200nA)
= ±438nA

In this case, the actual current output range is 0.7mA ±438nA or from 0.69956mA to 0.70044mA.

Source-Delay-Measure (SDM) cycle timing

The following timing information assumes that the SourceMeter is being triggered externally via the Trigger Link.

For Cases I through IV, it is assumed that the Output Auto-Off feature is enabled (:SOURce1:CLEar:AUTO ON), and the source setting changes for each triggered SDM cycle. The discussion is applicable for linear, log, and custom sweeps. It is also applicable to applications that use the "triggered source" feature (:SOURce1:VOLTage:TRIGger or SOURce1:CURRent:TRIGger). The discussion is not applicable for memory sweeps (:SOURce1:MEMory).

For Cases V and VI, it is assumed that the Output Auto-Off feature is disabled (:SOURce1:CLEar:AUTO OFF), and the source setting remains the same for each triggered SDM cycle. In this configuration, the static source remains on during all SDM cycles.

Definitions

Trigger Latency — Trigger latency is the time from when an external trigger event occurs to when the SourceMeter takes the appropriate action. It is from when an external trigger is detected in the Trigger Layer of the trigger model to when the trigger delay begins.

Trigger Delay — This is the time from when the external event is detected to when the source configuration begins. This is a user-programmable delay that can be set from 0.0000 seconds to 999.9999 seconds.

Source Configuration — This is the time it takes to configure the source DAC. For the following discussion, it is assumed that the range and polarity do not change when the source value is changed.

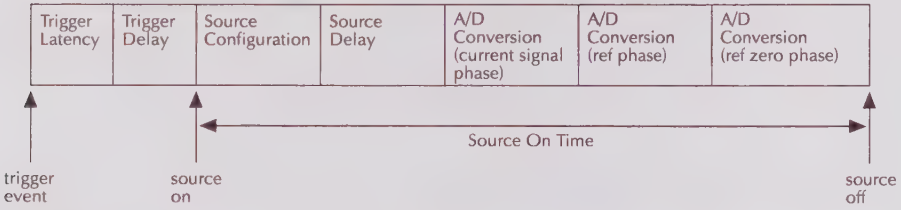
Source Delay — This is the time between the source configuration and the start of the first A/D conversion. This programmable delay is typically used to allow the source to settle before starting the measurement. With Auto-Delay enabled, 100µsec is added to the user-programmed source delay. The user-programmed delay can be set from 0.0000 seconds to 9999.998 seconds.

A/D Conversion — This is the time it takes to measure the specified A/D converter phase. In general, there are three A/D phases required to generate a voltage or current reading. These phases are often referred to as the "signal", "reference", and "reference zero" phases. The "signal" phase measures the input signal. The "reference" and "reference zero" phases are associated with a precision voltage reference inside the SourceMeter. By measuring all three phases, zero drift for the reading is reduced. A/D conversion time is programmable with 0.01 power line cycle resolution.

When Auto-Zero is enabled, all three phases are measured each time the SourceMeter is triggered. With Auto-Zero disabled, only the "signal" is measured. Hence, speed is increased at the expense of long term drift.

Firmware Overhead — This is the time associated with A/D communication, reading calibration, and other operations necessary to perform the SDM cycle. This time is not illustrated in the following timing diagrams.

Case I — Auto-Zero enabled and measuring a single function (i.e., current)



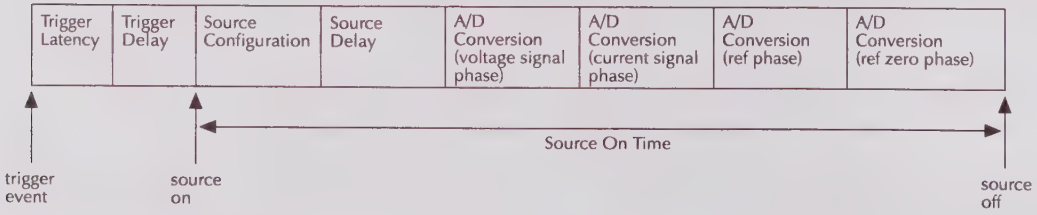
Trigger Latency:	225µsec max
Source Configuration:	50µsec max
A/D Conversion:	[NPLC Setting × (1 / power line frequency)] + 185µsec
Firmware Overhead:	1.8msec for Source V 2.15msec for Source I

Source On Time ≅ Source Configuration + Source Delay + (3 × A/D Conversion) + Firmware Overhead

Example: Source Delay = 0µsec
NPLC Setting = 0.01 PLC
Power Line Frequency = 60Hz

Source On Time ≅ 50µsec + 0 + [(3 × 0.01 × 1/60) + 185µsec] + 1.6msec
≅ 2.9msec for Source V
≅ 3.25msec for Source I

Case II — Auto-Zero enabled and measuring two functions (i.e., voltage and current)



Trigger Latency:	225µsec max
Source Configuration:	50µsec max
A/D Conversion:	[NPLC Setting × (1 / power line frequency)] + 185µsec
Firmware Overhead:	2.3msec for Source V 2.65msec for Source I

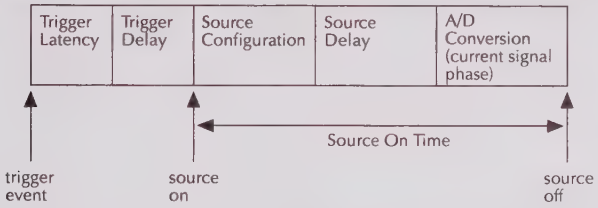
Source On Time ≅ Source Configuration + Source Delay + (4 × A/D Conversion) + Firmware Overhead

Example: Source Delay = 0µsec

NPLC Setting = 0.06 PLC
Power Line Frequency = 60Hz

Source On Time ≅ 50µsec + 0 + [(4 × 0.06 × 1/60) + 185µsec] + 2.6msec
≅ 7.1msec for Source V
≅ 7.45msec for Source I

Case III — Auto-Zero disabled and measuring one function (i.e., current)



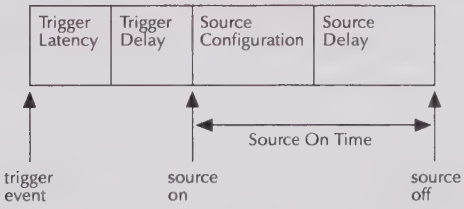
Trigger Latency:	225µsec max
Source Configuration:	50µsec max
A/D Conversion:	[NPLC Setting × (1 / power line frequency)] + 185µsec
Firmware Overhead:	300µsec for Source V 640µsec for Source I

Source On Time ≅ Source Configuration + Source Delay + A/D Conversion + Firmware Overhead

Example: Source Delay = 0µsec
NPLC Setting = 0.08 PLC
Power Line Frequency = 60Hz

Source On Time ≅ 50µsec + 0 + [(0.08 × 1/60) + 185µsec] + 40µsec
≅ 1.85msec for Source V
≅ 2.2msec for Source I

Case IV — Auto-Zero disabled and all measurements disabled



Trigger Latency:	225µsec max
Source Configuration:	50µsec max
Firmware Overhead:	310µsec for Source V 590µsec for Source I

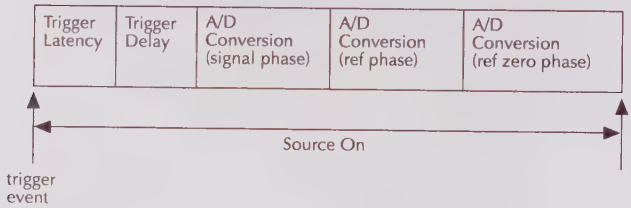
Source On Time ≅ Source Configuration + Source Delay + Firmware Overhead

Example: Source Delay = 0µsec

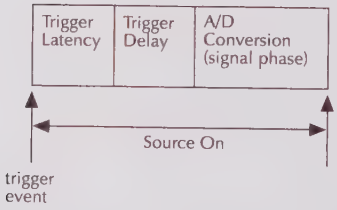
Source On Time ≅ 50µsec + 0 + 125µsec

≅ 360µsec for Source V
≅ 640µsec for Source I

Cases V and VI — Measure one function (i.e., current), Output Auto-Off disabled, and no source setting changes.



Auto-Zero: Enabled
Trigger Latency: 500µsec max



Auto Zero: Disabled
Trigger Latency: 100µsec max

The source turns on as soon as the output is turned on and remains on until the source is turned off. As shown in the two timing diagrams, the static source remains on for every measurement cycle. The Source-Delay portion of the SDM cycle is omitted. With Trigger Delay set to zero, Trigger Latency is the time from when the trigger event occurs to when the SourceMeter begins an A/D conversion.

B
Status and Error Messages

Table B-1
Status and error messages

Number	Error message	Event
-440	Query UNTERMINATED after indefinite response	EE
-430	Query DEADLOCKED	EE
-420	Query UNTERMINATED	EE
-410	Query INTERRUPTED	EE
-363	Input buffer overrun	EE
-362	Framing error in program message	EE
-361	Parity error in program message	EE
-360	Communications error	EE
-350	Queue overflow	SYS
-330	Self-test failed	EE
-314	Save/recall memory lost	EE
-315	Configuration memory lost	EE
-285	Program syntax error	EE
-284	Program currently running	EE
-282	Illegal program name	EE
-281	Cannot create program	EE
-260	Expression error	EE
-241	Hardware missing	EE
-230	Data corrupt or stale	EE
-225	Out of memory	EE
-224	Illegal parameter value	EE
-223	Too much data	EE
-222	Parameter data out of range	EE
-221	Settings conflict	EE
-220	Parameter error	EE
-215	Arm deadlock	EE
-214	Trigger deadlock	EE
-213	Init ignored	EE
-212	Arm ignored	EE
-211	Trigger ignored	EE
-210	Trigger error	EE
-202	Settings lost due to rtl	EE
-201	Invalid while in local	EE
-200	Execution error	EE
-178	Expression data not allowed	EE

Table B-1 (cont.)
Status and error messages

Number	Error message	Event
-171	Invalid expression	EE
-170	Expression error	EE
-168	Block data not allowed	EE
-161	Invalid block data	EE
-160	Block data error	EE
-158	String data not allowed	EE
-154	String too long	EE
-151	Invalid string data	EE
-150	String data error	EE
-148	Character data not allowed	EE
-144	Character data too long	EE
-141	Invalid character data	EE
-140	Character data error	EE
-128	Numeric data not allowed	EE
-124	Too many digits	EE
-123	Exponent too large	EE
-121	Invalid character in number	EE
-120	Numeric data error	EE
-114	Header suffix out of range	EE
-113	Undefined header	EE
-112	Program mnemonic too long	EE
-111	Header separator error	EE
-110	Command header error	EE
-109	Missing parameter	EE
-108	Parameter not allowed	EE
-105	GET not allowed	EE
-104	Data type error	EE
-103	Invalid separator	EE
-102	Syntax error	EE
-101	Invalid character	EE
-100	Command error	EE
+000	No error	SE

Table B-1 (cont.)
Status and error messages

Number	Error message	Event
	Measurement events:	
+100	Limit 1 failed	SE
+101	Low limit 2 failed	SE
+102	High limit 2 failed	SE
+103	Low limit 3 failed	SE
+104	High limit 3 failed	SE
+105	Active limit tests passed	SE
+106	Reading available	SE
+107	Reading overflow	SE
+108	Buffer available	SE
+109	Buffer full	SE
+111	OUTPUT interlock asserted	SE
+112	Temperature limit exceeded	SE
+113	Voltage limit exceeded	SE
+114	Source in compliance	SE
	Standard events:	
+200	Operation complete	SE
	Operation events:	
+300	Device calibrating	SE
+303	Device sweeping	SE
+305	Waiting in trigger layer	SE
+306	Waiting in arm layer	SE
+310	Re-entering the idle layer	SE
	Questionable events:	
+408	Questionable Calibration	SE
+414	Command Warning	SE
	Calibration errors:	
+500	Date of calibration not set	EE
+501	Next date of calibration not set	EE
+502	Calibration data invalid	EE
+503	DAC calibration overflow	EE
+504	DAC calibration underflow	EE
+505	Source offset data invalid	EE
+506	Source gain data invalid	EE
+507	Measurement offset data invalid	EE
+508	Measurement gain data invalid	EE
+509	Not permitted with cal locked	EE
+510	Not permitted with cal un-locked	EE

Table B-1 (cont.)
Status and error messages

Number	Error message	Event
	Lost data errors:	
+601	Reading buffer data lost	EE
+602	GPIB address lost	EE
+603	Power-on state lost	EE
+604	DC calibration data lost	EE
+605	Calibration dates lost	EE
+606	GPIB communication language lost	EE
	Communication errors:	
+700	Invalid system communication	EE
+701	ASCII only with RS-232	EE
	Additional command execution errors:	
+800	Illegal with storage active	EE
+801	Insufficient vector data	EE
+802	OUTPUT blocked by interlock	EE
+803	Not permitted with OUTPUT off	EE
+804	Expression list full	EE
+805	Undefined expression exists	EE
+806	Expression not found	EE
+807	Definition not allowed	EE
+808	Expression cannot be deleted	EE
+809	Source memory location revised	EE
+810	Output blocked by over-temp	EE
+811	Not an operator or number	EE
+812	Mismatched parenthesis	EE
+813	Not a number of data handle	EE
+814	Mismatched brackets	EE
+815	Too many parenthesis	EE
+816	Entire expression not parsed	EE
+817	Unknown token	EE
+818	Error parsing matissa	EE
+819	Error parsing exponent	EE
+820	Error parsing value	EE
+821	Invalid data handle index	EE
+822	Too small for sense range	EE
+823	Invalid with source read-back on	EE
+824	Cannot exceed compliance range	EE
+825	Invalid with auto-ohms on	EE
+826	Attempt to exceed power limit	EE

Table B-1 (cont.)
Status and error messages

Number	Error message	Event
+827	Invalid with ohms guard on	EE
+828	Invalid on 1 amp range (and 3A range)	EE
+900	Internal System Error	EE

EE = error event
SE = status event
SYS = system error event

NOTE *SCPI-confirmed messages are described in volume 2: Command Reference of the Standard commands for Programmable Instruments. Refer to the :SYSTem:ERRor? command.*

C
Operating Examples

Introduction

This appendix includes typical operating examples for the Model 2420 SourceMeter, including specific test parameters, SCPI command sequences, as well as several programming examples.

Operating examples include:

- Basic sweep operation
- Pass/fail limits testing
- Voltage coefficient testing

Basic sweep operation

One of the key capabilities of the Model 2420 SourceMeter is its ability to sweep and measure voltage and current simultaneously. The following operating example demonstrates the fundamental programming steps necessary to perform a basic sweep.

Sweep test example

As an example of sweep operation, assume the Model 2420 is to be used to generate the I-V characteristics of a diode. Many diode tests, such as breakdown voltage and leakage current, require only single-point measurements. Some, such as quality-assurance analysis of marginal parts, involve performing a complete I-V sweep for detailed analysis.

For the purposes of this test, assume the following basic sweep parameters:

Source Function: volts
Sense Function: current
Source Mode: sweep
Start Voltage: 600mV
Stop Voltage: 800mV
Step Voltage: 10mV
Current Compliance: 100mA
Source Delay: 100ms

Figure C-1 shows typical test connections for this test, and Figure C-2 shows a typical diode curve. Note that the diode anode is connected to INPUT/OUTPUT HI, and the cathode is connected to INPUT/OUTPUT LO. These connections are required to properly forward bias the diode for the purposes of the test. The test connections could also be reversed by using negative sweep voltage parameters.

Figure C-1
Connections for diode I-V tests

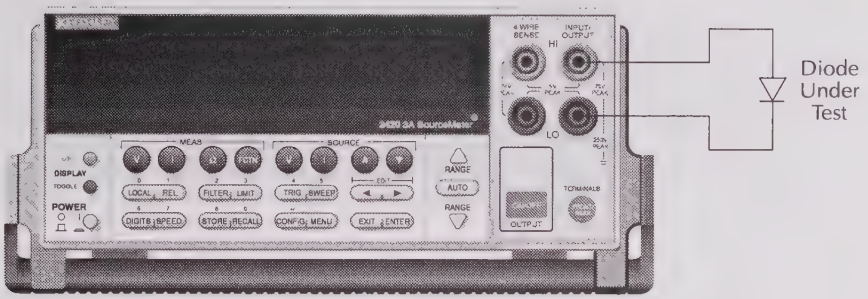
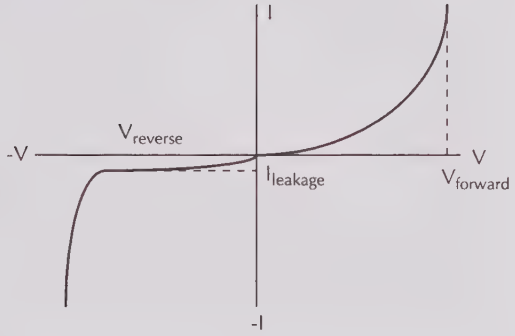


Figure C-2
Typical diode I-V curve



Sweep operation programming steps

The following programming steps are required for performing the I-V test sweep:

- Reset the Model 2420 to its default conditions.
- Select the volts source function.
- Program the current sense function.
- Set the current compliance to protect the diode.
- Program start, stop, and step voltages.
- Select the voltage sweep mode.
- Set the trigger count to the number of sweep points.
- Choose the desired source delay time.
- Turn output on.
- Trigger the sweep.
- Request and display the sweep data.

Table C-1 summarizes the basic SCPI command sequence for performing a basic sweep for the diode test described above. Program 1 at the end of this appendix demonstrates complete programming techniques.

Table C-1
Command sequence for basic sweep operation

Command	Description
*RST	Restore GPIB default conditions.
:SENS:FUNC:CONC OFF	Turn off concurrent functions.
:SOUR:FUNC VOLT	Volts source function.[1]
:SENS:FUNC 'CURR:DC'	Current sense function.[1]
:SENS:CURR:PROT 0.1	100mA current compliance.
:SOUR:VOLT:START 0.6	0.6V start voltage.
:SOUR:VOLT:STOP 0.8	0.8V stop voltage.
:SOUR:VOLT:STEP 0.01	0.01V step voltage.
:SOUR:VOLT:MODE SWE	Select volts sweep mode.[2]
:TRIG:COUN 21	Trigger count = # sweep points.[3]
:SOUR:DEL 0.05	50ms source delay.
:OUTPUT ON	Turn on source output.
:READ?	Trigger sweep, request data.

[1] These commands are not required in this case, since unit assumes these operating states after *RST but are included to demonstrate complete programming steps.
[2] This command should normally be sent after START, STOP, and STEP to avoid delays caused by rebuilding sweep when each command is sent.
[3] Trigger count should equal number of points in sweep: Points = (Stop-Start)/Step + 1.

SRQ on sweep done

The best way to determine when a sweep is done is to program the Model 2420 to generate an SRQ and have the controller detect the SRQ. You can then service the SRQ as usual. The three methods that can be used to generate an SRQ on sweep done are summarized below.

Note that Program 1 in this appendix uses the SRQ on OPC method to detect the end of the sweep.

SRQ on OPC

- Set up the sweep.
- Enable SRQ on OPC. (Send "*ESE 1; *SRE 32".)
- Send "INIT;*OPC" to trigger the unit.
- Wait for SRQ on OPC.

SRQ on MAV

- Set up the sweep.
- Enable SRQ on MAV. (Send "*SRE 16".)
- Send "INIT;*OPC?" to trigger the sweep.
- Wait for SRQ on MAV.

SRQ on IDLE

- Set up the sweep.
- Enable SRQ on IDLE. (Send ":STAT:OPER:ENAB 1024; *SRE128".)
- Send "INIT".
- Wait for SRQ on IDLE.

Pass/fail testing

The Model 2420 can perform pass/fail component testing using programmable parameter limits. When the instrument is interfaced with a material handler, production testing can automatically bin parts into good, bad, and marginal categories.

The three limits tests include:

- Limit 1: pass/fail on compliance.
- Limit 2: pass/fail on programmable upper and lower limits.
- Limit 3: pass/fail on programmable upper and lower limits.

Limits testing is generally performed from the widest to narrowest range. That is, Limit 1 tests the widest range, Limit 2 tests a more restricted range, and Limit 3 is assigned the narrowest range. The Model 2420 can be programmed to output a specific bit pattern based on the pass/fail limits for each via the Digital I/O port to control a material handler. The handler then sorts parts according to the specified criteria.

See "Limits tests" in Section 2 for more information.

Pass/fail test example

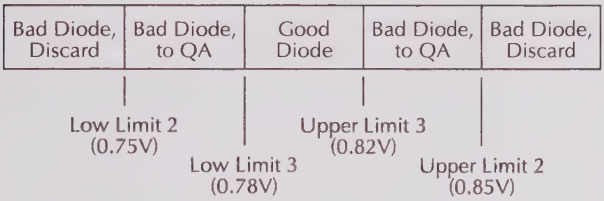
Diode breakdown voltage test is an example that readily lends itself to pass/fail analysis. This test verifies the reverse and often the forward voltage at which the device begins to show a large deviation in current for a small deviation in voltage. The test is performed by sourcing a specified current level and then measuring the resulting voltage drop. The voltage drop is then compared with one set of limits to determine if the diode passes, or fails and should be discarded. Voltage measurements for failing diodes are also compared against a more restricted range of limits to determine if they should be routed to QA (Quality Assurance) for further analysis.

Test parameters for this test include:

Source Function: current
Sense Function: voltage
Source Current: 100mA
Source Delay: 100ms
Limit 2 Upper Value: 0.85V
Limit 2 Lower Value: 0.75V
Limit 3 Upper Value: 0.82V
Limit 3 Lower Value: 0.78V

Figure C-3 demonstrates graphically how parts are sorted. Diodes with a voltage between 0.78V and 0.82V are considered good and will pass the limits test. Diodes that test with a slightly wider voltage range are routed to QA for analysis, while those with the largest voltage tolerance will be discarded.

Figure C-3
Diode pass/fail limits



Pass/fail test programming steps

The following steps are necessary to program the Model 2420 for pass/fail analysis:

- Reset the Model 2420 to its default conditions.
- Select the current source function.
- Program the volts sense function.
- Program the source current.
- Program the source delay.
- Program Limit 2 and Limit 3 upper and lower limit values.
- Program Digital I/O port configuration for pass/fail criteria.
- Turn output on.
- Trigger the reading.
- Request and display pass/fail analysis.

Table C-2 summarizes the basic SCPI command sequence for performing a limit test for the diode breakdown described above, and Table C-3 summarizes pass/fail parameters. Program 2 at the end of this appendix demonstrates complete programming techniques. Note that the test connections shown in Figure C-1 can be used for this test.

Table C-2
Command sequence for pass/fail tests

Command	Description
*RST	Restore GPIB default conditions.
:SENS:FUNC:CONC OFF	Turn off concurrent functions.
:SOUR:FUNC CURR	Current source function.
:SENS:FUNC 'VOLT:DC'	Volts sense function.
:SOUR:CURR:TRIG 0.1	Output 100mA when triggered.
:SOUR:DEL 0.1	100ms source delay.
:CALC2:FEED VOLT	Use voltage for limits comparison.
:CALC2:LIM2:UPP 0.85	Limit 2 upper value = 0.85V.
:CALC2:LIM2:LOW 0.75	Limit 2 lower value = 0.75V.
:CALC2:LIM3:UPP 0.82	Limit 3 upper value = 0.82V.
:CALC2:LIM3:LOW 0.78	Limit 3 lower value = 0.78V.
:CALC2:CLIM:PASS:SOUR2 1	Digital I/O port = 0001 (1) when test passes.
:CALC2:LIM2:UPP:SOUR2 2	Digital I/O port = 0010 (2) when upper Limit 2 fails.
:CALC2:LIM2:LOW:SOUR2 2	Digital I/O port = 0010 (2) when lower Limit 2 fails.
:CALC2:LIM3:UPP:SOUR2 3	Digital I/O port = 0011 (3) when upper Limit 3 fails.
:CALC2:LIM3:LOW:SOUR2 3	Digital I/O port = 0011 (3) when lower Limit 3 fails.
:CALC2:CLIM:BCON IMM	Update Digital I/O port immediately after test.
:CALC2:LIM1:STAT 0	Turn off Limit 1 test.
:CALC2:LIM2:STAT 1	Turn on Limit 2 test.
:CALC2:LIM3:STAT 1	Turn on Limit 3 test.
:OUTPUT ON	Turn on source output.
:INIT	Trigger reading and limits test.
:CALC2:LIM2:FAIL?	Query Limit 2 test results.
:CALC2:LIM3:FAIL?	Query Limit 3 test results.

Table C-3
Pass/fail test summary

Diode voltage range	Test result	Digital I/O port binary value	Handler bin number
0.78 to 0.82V	Pass	0001	1
0.75 to 0.78V or 0.82 to 0.85V	Send to QA	0010	2
<0.75, >0.85V	Discard	0011	3

Resistor voltage coefficient testing

Resistive elements will show a change in resistance with applied voltage. This change is known as the voltage coefficient and is computed automatically by the Model 2420 when the voltage coefficient math expression is used. (See Section 2 for complete details on factory-defined math expressions.) Although such changes in resistance with voltage are present in virtually all resistors to at least some degree, voltage coefficients are most noticeable in high-value resistors (>$10^{10}\Omega$).

Resistor voltage coefficient test example

Figure C-4 shows the tests connections for the voltage coefficient tests. Key test parameters for this test are:

Source Function: volts
Sense Functions: all
Source Delay: 1sec
Start Voltage: 10V
Stop Voltage: 50V
Math Expression: voltage coefficient

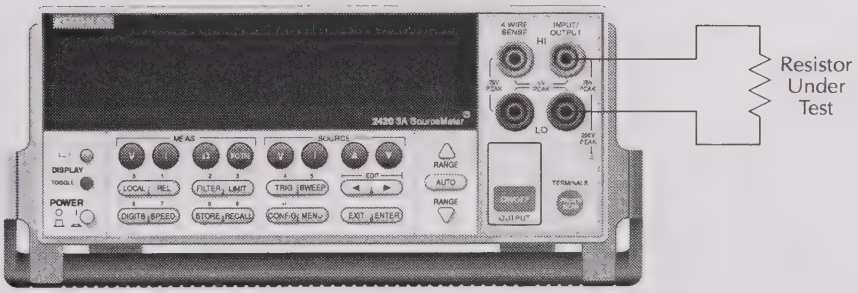


Figure C-4
Connections for voltage coefficient tests

Programming steps

The following programming steps are required to perform the voltage coefficient test previously described:

- Reset the Model 2420 to its default conditions.
- Select the volts source function.
- Enable all sense functions.
- Select the manual resistance mode.
- Program start and stop voltages.
- Select the voltage sweep mode.
- Set both the trigger count and the number of sweep points to two.
- Choose the desired source delay time.
- Enable the voltage coefficient math expression.
- Turn output on.
- Trigger the sweep.
- Request and display the voltage coefficient data.

Table C-4 summarizes the basic SCPI command sequence for performing the resistor voltage coefficient test described. Program 3 at the end of this appendix demonstrates complete programming techniques.

Table C-4
Voltage coefficient test commands

Command	Description
*RST	Reset unit to GPIB defaults.
:SENS:FUNC:ON:ALL	Enable all sense functions.
:SENS:RES:MODE MAN	Manual resistance mode.
:SOUR:FUNC VOLT	Volts source function.
:SOUR:VOLT:STAR 10	10V start voltage.
:SOUR:VOLT:STOP 50	50V stop voltage.
:SOUR:VOLT:MODE SWE	Volts sweep mode.
:SOUR:SWE:POIN 2	Sweep points = 2.
:TRIG:COUN 2	Trigger count = 2.
:CALC:MATH:EXPR:NAME 'VOLTCOEF'	Select voltage coefficient math expression.
:CALC:STAT ON	Enable math.
:OUTPUT ON	Turn on output.
:INIT	Trigger sweep.
:CALC:DATA?	Request voltage coefficient data.

Example programs

The following example programs demonstrate the basic programming steps previously outlined. The example programs are:

- Program 1: Basic sweep operation
- Program 2: Pass/fail testing
- Program 3: Voltage coefficient testing

Computer hardware requirements

The following computer hardware is required to run the example programs:

- IBM PC compatible computer.
- Keithley KPC-488.2, KPS-488.2, or KPC-488.2AT, or CEC PC-488 IEEE-488 interface for the computer.
- Shielded IEEE-488 connecting cable (Keithley Model 7007)

Software requirements

In order to use the example programs, you will need the following computer software:

- Microsoft QBasic (supplied with MS-DOS 5.0 or later).
- MS-DOS version 5.0 or later.
- HP-style Universal Language Driver, CECHP.EXE (supplied with Keithley and CEC interface cards listed above).

General program instructions

1. With the power off, connect the Model 2420 to the IEEE-488 interface of the computer. Be sure to use a shielded IEEE-488 cable for bus connections.
2. Turn on the computer and the Model 2420. For rated accuracy, allow the Model 2420 to warm up for at least one hour before performing any tests.
3. Make sure the Model 2420 is set for a primary address of 24. (Use the front panel MENU/GPIB selection to check or change the address.)
4. Make sure the computer bus driver software (CECHP.EXE) is properly initialized.
5. Enter the QBasic editor, and enter in the following program.. Check thoroughly for errors, and then save it using a convenient filename.
6. Run the program, and observe that appropriate test is run.

Basic sweep operation program

Program 1 demonstrates basic sweep operation and testing diode I-V characteristics. Figure C-5 shows an example plot of diode data generated by the charting feature of a spreadsheet program.

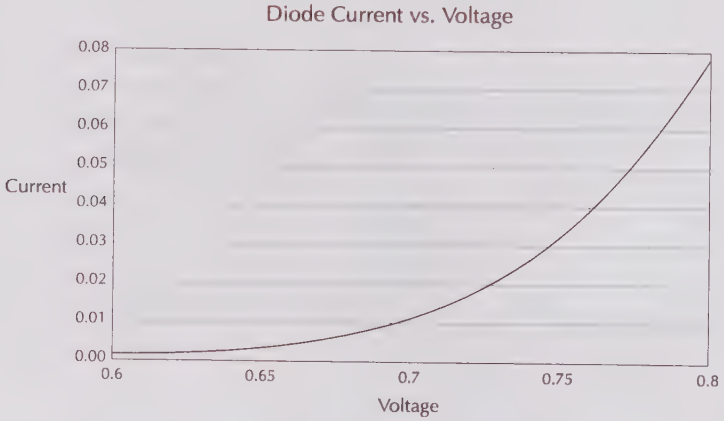


Figure C-5
Sweep program example plot

Enhancements to the command sequence discussed earlier include:

- The :FORM:ELEM command is used to select only voltage and current data fields for output.
- The :SOUR:SWE:POIN? query returns the number of points in the sweep. The points variable is then used to program the trigger count and to set the program loop counter used for data input.
- Sweep done is detected by programming the instrument to generate an SRQ on OPC.

Program 1 Basic sweep operation

```
' Program 1: Basic sweep operation
' Model 2420 primary address = 24
OPEN "IEEE" FOR OUTPUT AS #1                    ' Open IEEE-488 output path.
OPEN "IEEE" FOR INPUT AS #2                     ' Open IEEE-488 input path.
PRINT #1, "INTERM CRLF"                         ' Set input terminator.
PRINT #1, "OUTTERM LF"                          ' Set output terminator.
PRINT #1, "REMOTE 24"                           ' Put 2420 in remote.
PRINT #1, "OUTPUT 24;*RST;*CLS"                 ' Restore GPIB defaults.
PRINT #1, "OUTPUT 24;*ESE 1;*SRE 32"            ' Enable SRQ on OPC.
PRINT #1, "OUTPUT 24;:SENS:FUNC:CONC OFF"       ' Disable concurrent mode.
PRINT #1, "OUTPUT 24;:SOUR:FUNC VOLT"           ' Volts source function.
PRINT #1, "OUTPUT 24;:SENS:FUNC 'CURR:DC'"      ' Current sense function.
PRINT #1, "OUTPUT 24;:SENS:CURR:PROT 0.1"       ' 0.1A compliance.
PRINT #1, "OUTPUT 24;:SOUR:VOLT:START 0.6"      ' 0.6V start V.
PRINT #1, "OUTPUT 24;:SOUR:VOLT:STOP 0.8"       ' 0.8V stop V.
PRINT #1, "OUTPUT 24;:SOUR:VOLT:STEP 0.01"      ' 0.01V step V.
PRINT #1, "OUTPUT 24;:SOUR:VOLT:MODE SWE"       ' Sweep mode.
PRINT #1, "OUTPUT 24;:SOUR:DEL 0.05"            ' 50ms delay.
PRINT #1, "OUTPUT 24;:FORM:ELEM VOLT,CURR"      ' Set data format.
PRINT #1, "OUTPUT 24;:SOUR:SWE:POIN?"           ' Request sweep points.
PRINT #1, "ENTER 24"
INPUT #2, Points
PRINT #1, "OUTPUT 24;:TRIG:COUN"; Points        ' Set trigger count.
PRINT #1, "OUTPUT 24;:OUTPUT ON"                ' Turn on output.
PRINT #1, "OUTPUT 24;:INIT;*OPC"                ' Trigger sweep, OPC.
CLS : PRINT "Performing sweep..."
    DO: PRINT #1, "SRQ?"                        ' Request SRQ status.
    INPUT #2, SRQ                               ' Input SRQ status.
LOOP UNTIL SRQ                                  ' Loop until SRQ occurs.
PRINT #1, "OUTPUT 24;:FETCH?"
PRINT #1, "ENTER 24"                            ' Address 2420 to talk.
PRINT : PRINT "Voltage", "Current": PRINT
FOR I = 1 TO Points                             ' Loop for all points.
INPUT #2, volts, current                        ' Input sweep data.
PRINT volts, current
NEXT I
PRINT #1, "OUTPUT 24;:OUTPUT OFF"               ' Turn off output.
PRINT #1, "LOCAL 24"                            ' Restore local operation.
CLOSE
END
```

Limits testing program

Program 2 performs the pass/fail diode test previously described. Model 2420 SCPI commands appear in DATA statements, and thus are not documented in the source code. See Table C-2 for a description of commands.

Program 2 Limits testing

```
' Program 2: pass/fail limits testing.
' Model 2420 primary address = 24
OPEN "IEEE" FOR OUTPUT AS #1                          ' Open IEEE-488 output path.
OPEN "IEEE" FOR INPUT AS #2                           ' Open IEEE-488 input path.
PRINT #1, "INTERM CRLF"                               ' Set input terminator.
PRINT #1, "OUTTERM LF"                                ' Set output terminator.
PRINT #1, "REMOTE 24"                                 ' Put 2420 in remote.
CLS : PRINT "Performing test..."
FOR I = 1 TO 25                                       ' Set up 2420.
READ Cmd$                                             ' Read command string.
PRINT #1, "OUTPUT 24;"; Cmd$                          ' Send command to 2420.
IF I = 23 OR I = 24 THEN PRINT #1, "ENTER 24"
IF I = 23 THEN INPUT #2, Limit2                       'Input failure states.
IF I = 24 THEN INPUT #2, Limit3
NEXT I
PRINT #1, "LOCAL 24"
CLOSE
IF Limit2 = 0 AND Limit3 = 0 THEN PRINT "Diode passed."       ' Display results.
IF Limit2 = 1 THEN
    PRINT "Discard diode."
    ELSE IF Limit3 = 1 THEN PRINT "Send diode to QA."
END IF
END
CmdList:                                              ' Command list.
DATA "*RST",":SENS:FUNC:CONC OFF",":SOUR:FUNC CURR",":SENS:FUNC 'VOLT:DC'"
DATA ":SOUR:CURR:TRIG 0.1",":SOUR:DEL 0.1",":CALC2:FEED VOLT"
DATA ":CALC2:LIM2:UPP 0.85",":CALC2:LIM2:LOW 0.75",":CALC2:LIM3:UPP 0.82"
DATA ":CALC2:LIM3:LOW 0.78",":CALC2:CLIM:PASS:SOUR2 1"
DATA ":CALC2:LIM2:UPP:SOUR2 2",":CALC2:LIM2:LOW:SOUR2 2"
DATA ":CALC2:LIM3:UPP:SOUR2 3",":CALC2:LIM3:LOW:SOUR2 3"
DATA ":CALC2:CLIM:BCON IMM",":CALC2:LIM1:STAT 0"
DATA ":CALC2:LIM2:STAT 1",":CALC2:LIM3:STAT 1",":OUTPUT ON"
DATA ":INIT",":CALC2:LIM2:FAIL?",":CALC2:LIM3:FAIL?",":OUTPUT OFF"
```

Voltage coefficient test program

Program 3 demonstrates the basic techniques for performing the voltage coefficient test. The program uses values of 10V and 50V for V1 and V2, respectively. At the conclusion of the test, the voltage coefficient of the resistor being tested is displayed.

Program 3 Voltage coefficient test

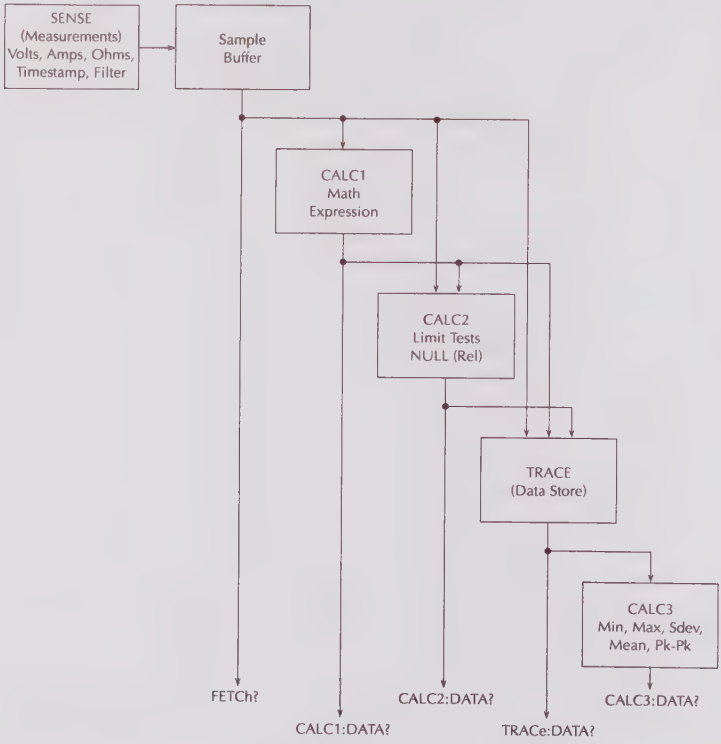
```
' Program 3: Resistor voltage coefficient test
' Model 2420 primary address = 24
OPEN "IEEE" FOR OUTPUT AS #1                          ' Open IEEE-488 output path.
OPEN "IEEE" FOR INPUT AS #2                           ' Open IEEE-488 input path.
PRINT #1, "INTERM CRLF"                               ' Set input terminator.
PRINT #1, "OUTTERM LF"                                ' Set output terminator.
PRINT #1, "REMOTE 24"                                 ' Put 2420 in remote.
PRINT #1, "OUTPUT 24;*RST;*CLS"                       ' Restore GPIB defaults.
PRINT #1, "OUTPUT 24;*ESE 1;*SRE 32"                  ' Enable SRQ on OPC.
PRINT #1, "OUTPUT 24;:SENS:FUNC:ON:ALL"               ' Enable all functions.
PRINT #1, "OUTPUT 24;:SENS:RES:MODE MAN"              ' Manual resistance mode.
PRINT #1, "OUTPUT 24;:SOUR:FUNC VOLT"                 ' Volts source function.
PRINT #1, "OUTPUT 24;:SOUR:VOLT:START"; 10            ' V1 = 10V
PRINT #1, "OUTPUT 24;:SOUR:VOLT:STOP"; 50             ' V2 = 50V.
PRINT #1, "OUTPUT 24;:SOUR:VOLT:MODE SWE"             ' Sweep mode.
PRINT #1, "OUTPUT 24;:SOUR:SWE:POIN 2"                ' Two-point sweep.
PRINT #1, "OUTPUT 24;:TRIG:COUN "; 2                  ' Set trigger count.
PRINT #1, "OUTPUT 24;:SOUR:DEL 1"                     ' 1s delay.
PRINT #1, "OUTPUT 24;:CALC:MATH:EXPR:NAME 'VOLTCOEF'"      ' V coefficient.
PRINT #1, "OUTPUT 24;:CALC:STAT ON"                   ' Enable calculations.
PRINT #1, "OUTPUT 24;:OUTPUT ON"                      ' Turn on output.
PRINT #1, "OUTPUT 24;:INIT;*OPC"                      ' Trigger sweep, OPC.
CLS : PRINT "Performing test..."
DO: PRINT #1, "SRQ?"                                  ' Request SRQ status.
    INPUT #2, SRQ                                     ' Input SRQ status.
LOOP UNTIL SRQ                                        ' Loop until SRQ occurs.
PRINT #1, "OUTPUT 24;:CALC:DATA?"                     ' Request calc data.
PRINT #1, "ENTER 24"                                  ' Address 2420  to talk.
LINE INPUT #2, Data$                                  ' Input data string.
PRINT "Voltage coefficient = "; Data$; " %/V"
PRINT #1, "OUTPUT 24;:OUTPUT OFF"                     ' Turn off output.
PRINT #1, "LOCAL 24"                                  ' Restore local operation.
CLOSE
END
```

D
Data Flow

Introduction

Data flow for remote operation is summarized by the block diagram shown in Figure D-1. Refer to this block diagram for the following discussion.

Figure D-1
Data flow block diagram



The SENSE block represents the basic measured readings of voltage, current and resistance. If Filter is enabled, the readings will be filtered. The SENSE block also measures time for the timestamp.

When the INITiate command is sent, the programmed number of source-measure operations are performed and the respective data is temporarily stored in the Sample Buffer. For example, if 20 source-measure operations were performed, then 20 sets of data will be stored in the Sample Buffer. Data from this buffer is then routed to other enabled data flow blocks.

Assuming that all functions are enabled, the data that is output by the read commands (FETCh?, CALC1:DATA?, CALC2:DATA?, TRACe:DATA? and CALC3:DATA?) depend on which data elements are selected by the FORMat:ELEMents command.With all elements selected, available data will include voltage, current and resistance readings as well as the

timestamp and status information. Note that if a measurement function is not enabled, then either the NAN (not a number) value or the source reading will instead be used (see FORMat Subsystem for details).

After all source-measure operations are completed the SourceMeter returns to the idle state. The data stored in the Sample Buffer will remain there until data from another source-measure cycle overwrites the buffer. Data in the Sample Buffer is lost if the SourceMeter goes to the local state (REM annunciator off).

NOTE *With no data in the Sample Buffer, the FETCh?, CALCulate1:DATA? and CALCulate2:DATA? commands to read data will display the message "Data corrupt or stale".*

FETCh?

This command is used to read data stored in the Sample Buffer. If for example, there are 20 data arrays stored in the Sample Buffer, then all 20 data arrays will be sent to the computer when FETCh? is executed. Note that FETCh? does not affect data in the Sample Buffer. Thus, subsequent executions of FETCh? acquire the same data.

The READ? command performs an INITiate and then a FETCh? The INITiate triggers a new source-measure cycle which puts new data in the Sample Buffer. FETCh? reads that new data. The MEASure? command places the SourceMeter in a "one-shot" source-measure mode and then performs a READ?. See "Signal oriented measurement commands" in Section 4 for more information on READ? and MEASure?.

CALCulate[1]:DATA?

If CALCulate1 is enabled, Sample Buffer data is fed to the CALC1 block where the results for the selected math expression are calculated. The CALC1:DATA? command will read the results of the math expression. If, for example, 20 data arrays in the Sample Buffer yield 10 math expression results, then CALC1:DATA? will acquire 10 readings (results).

CALCulate2:DATA?

If CALCulate2 is enabled, Sample Buffer data and CALC1 math expression results become available to the CALC2 block for limit testing. Depending on the selected feed, limit testing can be performed on the voltage, current, resistance or timestamp readings of Sample Buffer data, or it can be performed on the CALC1 math expression results. If NULL (rel) is enabled, the readings used for limit testing will be the results of the null operation.

The CALCulate2:DATA? command acquires the readings used for limit testing.

TRACe:DATA?

If the data store is enabled, Sample Buffer data, CALC1 results and CALC2 readings become available to the TRACE block for storage. The selected feed determines which group of readings are stored.

The TRACe:DATA? command reads the entire contents of the data store.

CALCulate3:DATA?

Statistical information (minimum, maximum, mean, standard deviation and peak-to-peak) is available for measure readings stored in the buffer. If the readings in the data store came directly from the Sample Buffer, then the selected statistic calculation will be performed on all enabled measurement functions. The calculation results are returned in the following fixed order:

VOLTage result, CURRent result, RESistance result

When the TRACE buffer is feeding off CALC1 or CALC2, the selected statistic calculation is performed on the selected feed. Thus, a single statistic result is acquired for each reading stored in the data store.

The CALCulate3:DATA? command acquires the results of the selected calculation.

E
Factory Defaults

Setting	BENCH default	GPIB default
A/D Controls:		
Auto-zero	On	On
Line frequency	No effect	No effect
Beeper	On	On
Data Store	No effect	No effect
Digital output	HI, HI, HI, HI	HI, HI, HI, HI
Digits	5½	5½
FCTN	Power (off)	Power (off)
Filter:	Off	Off
Averaging type	Repeat	Repeat
Count	10	10
GPIB address	No effect	No effect
Guard	Cable	Cable
Limit tests:		
Limit1	Disabled	Disabled
Fail mode	IN compliance	IN compliance
Fail pattern	HI, HI, HI, HI	HI, HI, HI, HI
Limit2 and Limit3	Disabled	Disabled
Low limit	0.0	0.0
Fail pattern	HI, HI, HI, HI	HI, HI, HI, HI
High limit	0.0	0.0
Fail pattern	HI, HI, HI, HI	HI, HI, HI, HI
Pass pattern	HI, HI, HI, HI	HI, HI, HI, HI
Pass Source Memory Sweep Location	NEXT	NEXT
Clear digital output:		
Auto-clear	Disabled	Disabled
Delay	0.0 sec	0.0 sec
Clear pattern	HI, HI, HI, HI	HI, HI, HI, HI
Binning control	IMMEDIATE	IMMEDIATE
Numbers	No effect	No effect
Ohms source mode	Auto	Auto
Offset Compensated Ohms	Off	Off
Output	Off	Off
Interlock	Disabled	Disabled
Off State	Normal	Normal
Auto-off	Disabled	Disabled
Power-on default	No effect	No effect
Ranging (measure):		
Auto range	Enabled	Enabled
Rel	Off	Off
Value	0.0	0.0
RS-232	No effect	No effect

Setting	BENCH default	GPIB default
Sense mode	2-wire	2-wire
Source delay	1 mse	1 msec
Auto-delay	Enabled	Enabled
Speed	Normal (1 PLC)	Normal (1 PLC)
Sweep	Linear staircase	Linear staircase
Start	0V or 0A	0V or 0A
Stop	0V or 0A	0V or 0A
Step	0V or 0A	0V or 0A
Sweep count	1	1
Sweep Pts	2500	2500
Source ranging	Best fixed	Best fixed
Voltage protection	36V	NONE
Triggering:		
Arm layer:		
Event	Immediate	Immediate
Count	1	1
Output trigger	Line #2, Off	Line #2, Off
Trigger layer:		
Event	Immediate	Immediate
Count	1	1
Output triggers	Line #2, All off	Line #2, All off
Delay	0.0 sec	0.0 sec

F

IEEE - 488 Bus Overview

Introduction

Basically, the IEEE-488 bus is simply a communication system between two or more electronic devices. A device can be either an instrument or a computer. When a computer is used on the bus, it serves to supervise the communication exchange between all the devices and is known as the controller. Supervision by the controller consists of determining which device will talk and which device will listen. As a talker, a device will output information and as a listener, a device will receive information. To simplify the task of keeping track of the devices, a unique address number is assigned to each one.

On the bus, only one device can talk at a time and is addressed to talk by the controller. The device that is talking is known as the active talker. The devices that need to listen to the talker are addressed to listen by the controller. Each listener is then referred to as an active listener. Devices that do not need to listen are instructed to unlisten. The reason for the unlisten instruction is to optimize the speed of bus information transfer since the task of listening takes up bus time.

Through the use of control lines, a handshake sequence takes place in the transfer process of information from a talker to a listener. This handshake sequence helps ensure the credibility of the information transfer. The basic handshake sequence between an active controller (talker) and a listener is as follows:

1. The listener indicates that it is ready to listen.
2. The talker places the byte of data on the bus and indicates that the data is available to the listener.
3. The listener, aware that the data is available, accepts the data and then indicates that the data has been accepted.
4. The talker, aware that the data has been accepted, stops sending data and indicates that data is not being sent.
5. The listener, aware that there is no data on the bus, indicates that it is ready for the next byte of data.

Bus description

The IEEE-488 bus, which is also frequently referred to a the GPIB (General Purpose Interface Bus), was designed as a parallel transfer medium to optimize data transfer without using an excessive number of bus lines. In keeping with this goal, the bus has only eight data lines that are used for both data and with most commands. Five bus management lines and three handshake lines round out the complement of bus signal lines

A typical set up for controlled operation is shown in Figure F-1. Generally, a system will contain one controller and a number of other instruments to which the commands are given. Device operation is categorized into three operators: controller, talker and listener. The controller does what its name implies; it controls the instruments on the bus. The talker sends data while a listener receives data. Depending on the type of instrument, any particular device can be a talker only, a listener only or both a talker and listener.

There are two categories of controllers: system controller, and basic controller. Both are able to control other instruments, but only the system controller has the absolute authority in the system. In a system with more than one controller, only one controller may be active at any given time. Certain protocol is used to pass control from one controller to another.

The IEEE-488 bus is limited to 15 devices, including the controller. Thus, any number of talkers and listeners up to that limit may be present on the bus at one time. Although several devices may be commanded to listen simultaneously, the bus can have only one active talker, or communications would be scrambled.

A device is placed in the talk or listen state by sending an appropriate talk or listen command. These talk and listen commands are derived from an instrument's primary address. The primary address may have any value between 0 and 31, and is generally set by rear panel DIP switches or programmed in from the front panel of the instrument. The actual listen address value sent out over the bus is obtained by ORing the primary address with #H20. For example, if the primary address is #H16, the actual listen address is #H36 (#H36 = #H16 + #H20). In a similar manner, the talk address is obtained by ORing the primary address with #H40. With the present example, the talk address derived from a primary address of 16 decimal would be #H56 (#H56 = #H16 + #H40).

The IEEE-488 standards also include another addressing mode called secondary addressing. Secondary addresses lie in the range of #H60-#H7F. Note, however, that many devices, including the Model 2420, do not use secondary addressing.

Once a device is addressed to talk or listen, the appropriate bus transactions take place. For example: if the instrument is addressed to talk, it places its data string on the bus one byte at a time. The controller reads the information and the appropriate software can be used to direct the information to the desired location.

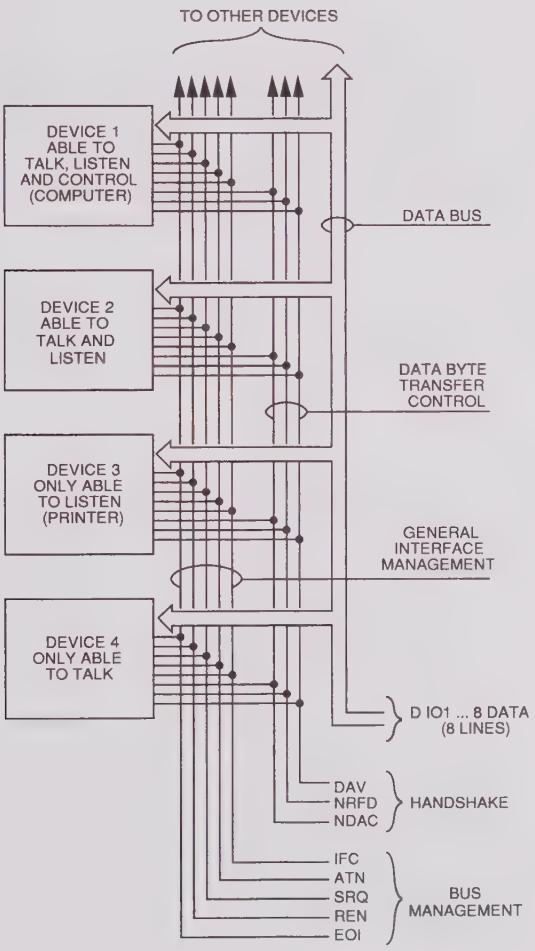


Figure F-1
IEEE-488 bus configuration

Bus lines

The signal lines on the IEEE-488 bus are grouped into three different categories: data lines, management lines and handshake lines. The data lines handle bus data and commands, while the management and handshake lines ensure that proper data transfer and operation takes place. Each bus line is active low, with approximately zero volts representing a logic 1 (true). The following paragraphs describe the operation of these lines.

Data lines

The IEEE-488 bus uses eight data lines that transfer data one byte at a time. DIO1 (Data Input/Output) through DIO8 (Data Input/Output) are the eight data lines used to transmit both data and multiline commands and are bidirectional. The data lines operate with low true logic.

Bus management lines

The five bus management lines help to ensure proper interface control and management. These lines are used to send the uniline commands.

ATN (Attention) — The ATN line is one of the more important management lines in that the state of this line determines how information on the data bus is to be interpreted.

IFC (Interface Clear) — As the name implies, the IFC line controls clearing of instruments from the bus.

REN (Remote Enable) —The REN line is used to place the instrument on the bus in the remote mode.

EOI (End or Identify) — The EOI is usually used to mark the end of a multi-byte data transfer sequence.

SRQ (Service Request) — This line is used by devices when they require service from the controller.

Handshake lines

The bus handshake lines operate in an interlocked sequence. This method ensures reliable data transmission regardless of the transfer rate. Generally, data transfer will occur at a rate determined by the slowest active device on the bus.

One of the three handshake lines is controlled by the source (the talker sending information), while the remaining two lines are controlled by accepting devices (the listener or listeners receiving the information). The three handshake lines are:

DAV (DATA VALID) — The source controls the state of the DAV line to indicate to any listening devices whether or not data bus information is valid.

NRFD (Not Ready For Data) — The acceptor controls the state of NRFD. It is used to signal to the transmitting device to hold off the byte transfer sequence until the accepting device is ready.

NDAC (Not Data Accepted) — NDAC is also controlled by the accepting device. The state of NDAC tells the source whether or not the device has accepted the data byte.

The complete handshake sequence for one data byte is shown in Figure F-2. Once data is placed on the data lines, the source checks to see that NRFD is high, indicating that all active devices are ready. At the same time, NDAC should be low from the previous byte transfer. If these conditions are not met, the source must wait until NDAC and NRFD have the correct status. If the source is a controller, NRFD and NDAC must be stable for at least 100nsec after ATN is set true. Because of the possibility of a bus hang up, many controllers have time-out routines that display messages in case the transfer sequence stops for any reason.

Once all NDAC and NRFD are properly set, the source sets DAV low, indicating to accepting devices that the byte on the data lines is now valid. NRFD will then go low, and NDAC will go high once all devices have accepted the data. Each device will release NDAC at its own rate, but NDAC will not be released to go high until all devices have accepted the data byte.

The sequence just described is used to transfer both data, talk and listen addresses, as well as multiline commands. The state of the ATN line determines whether the data bus contains data, addresses or commands as described in the following paragraph.

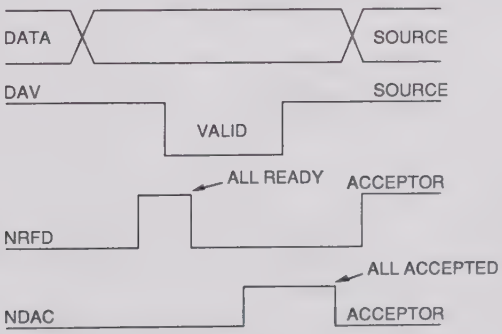


Figure F-2
IEEE-488 handshake sequence

Bus commands

The instrument may be given a number of special bus commands through the IEEE-488 interface. This section briefly describes the purpose of the bus commands which are grouped into the following three categories.

1. Uniline Commands — Sent by setting the associated bus lines true. For example, to assert REN (Remote Enable), the REN line would be set low (true).
2. Multiline Commands — General bus commands which are sent over the data lines with the ATN line true (low).
3. Common Commands — Commands that are common to all devices on the bus; sent with ATN high (false).
4. SCPI Commands — Commands that are particular to each device on the bus; sent with ATN (false).

These bus commands and their general purpose are summarized in Table F-1.

Table F-1
IEEE-488 bus command summary

Command type	Command	State of ATN line	Comments
Uniline	REN (Remote Enable)	X	Set up devices for remote operation.
	EOI	X	Marks end of transmission.
	IFC (Interface Clear)	X	Clears interface.
	ATN (Attention)	Low	Defines data bus contents.
	SRQ	X	Controlled by external device.
Multiline Universal	LLO (Local Lockout)	Low	Locks our local operation.
	DCL (Device Clear)	Low	Returns device to default conditions.
	SPE (Serial Enable)	Low	Enables serial polling.
	SPD (Serial Poll Disable)	Low	Disables serial polling.
Addressed	SDC (Selective Device Clear)	Low	Returns unit to default conditions.
	GTL (Go To Local)	Low	Returns device to local.
Unaddressed	UNL (Unlisten)	Low	Removes all listeners from the bus.
	UNT (Untalk)	Low	Removes any talkers from the bus.
Common	—	High	Programs IEEE-488.2 compatible instruments for common operations.
SCPI	—	High	Programs SCPI compatible instruments for particular operations.

Uniline commands

ATN, IFC and REN are asserted only by the controller. SRQ is asserted by an external device. EOI may be asserted either by the controller or other devices depending on the direction of data transfer. The following is a description of each command. Each command is sent by setting the corresponding bus line true.

REN (Remote Enable) — REN is sent to set up instruments on the bus for remote operation. When REN is true, devices will be removed from the local mode. Depending on device con used to positively identify the last byte in a multi-byte transfer sequence, thus allowing data words of various lengths to be transmitted easily.

IFC (Interface Clear) — IFC is used to clear the interface and return all devices to the talker and listener idle states.

ATN (Attention) — The controller sends ATN while transmitting addresses or multiline commands.

SRQ (Service Request) — SRQ is asserted by a device when it requires service from a controller.

Universal multiline commands

Universal commands are those multiline commands that require no addressing. All devices equipped to implement such commands will do so simultaneously when the commands are transmitted. As with all multiline commands, these commands are transmitted with ATN true.

LLO (Local Lockout) — LLO is sent to the instrument to lock out the LOCAL key and thus all their front panel controls.

DCL (Device Clear) — DCL is used to return instruments to some default state. Usually, instruments return to their power-up conditions.

SPE (Serial Poll Enable) — SPE is the first step in the serial polling sequence which is used to determine which device has requested service.

SPD (Serial Poll Disable) — SPD is used by the controller to remove all devices on the bus from the serial poll mode and is generally the last command in the serial polling sequence.

Addressed multiline commands

Addressed commands are multiline commands that must be preceded by the device listen address before that instrument will respond to the command in question. Note that only the addressed device will respond to these commands. Both the commands and the address preceding it are sent with ATN true.

SDC (Selective Device Clear) — The SDC command performs essentially the same function as the DCL command except that only the addressed device responds. Generally, instruments return to their power-up default conditions when responding to the SDC command.

GTL (Go To Local) — The GTL command is used to remove instruments from the remote mode. With some instruments, GTL also unlocks front panel controls if they were previously locked out with the LLO command.

GET (Group Execute Trigger) — The GET command is used to trigger devices to perform a specific action that depends on device configuration (for example, take a reading). Although GET is an addressed command, many devices respond to GET without addressing.

Address commands

Addressed commands include two primary command groups and a secondary address group. ATN is true when these commands are asserted. The commands include:

LAG (Listen Address Group) — These listen commands are derived from an instrument's primary address and are used to address devices to listen. The actual command byte is obtained by ORing the primary address with #H20.

TAG (Talk Address Group) — The talk commands are derived from the primary address by ORing the address with #H40. Talk commands are used to address devices to talk.

SCG (Secondary Command Group) — Commands in this group provide additional addressing capabilities. Many devices (including the Model 2420) do not use these commands.

Unaddress commands

The two unaddress commands are used by the controller to remove any talkers or listeners from the bus. ATN is true when these commands are asserted.

UNL (Unlisten) — Listeners are placed in the listener idle state by the UNL command.

UNT (Untalk) — Any previously commanded talkers will be placed in the talker idle state by the UNT command.

Common commands

Common commands are commands that are common to all devices on the bus. These commands are designated and defined by the IEEE-488.2 standard.

Generally, these commands are sent as one or more ASCII characters that tell the device to perform a common operation, such as reset. The IEEE-488 bus treats these commands as data in that ATN is false when the commands are transmitted.

SCPI commands

SCPI commands are commands that are particular to each device on the bus. These commands are designated by the instrument manufacturer, and are based on the instrument model defined by the Standard Commands for Programmable Instruments (SCPI) Consortium's SCPI standard.

Generally, these commands are sent as one or more ASCII characters that tell the device to perform a particular operation, such as setting a range or closing a relay. The IEEE-488 bus treats these commands as data in that ATN is false when the commands are transmitted.

Command codes

Command codes for the various commands that use the data lines are summarized in Figure F-3. Hexadecimal and the decimal values for the various commands are listed in Table F-2.

Table F-2
Hexadecimal and decimal command codes

Command	Hex value	Decimal value
GTL	01	1
SDC	04	4
GET	08	8
LLO	11	17
DCL	14	20
SPE	18	24
SPD	19	25
LAG	20-3F	32-63
TAG	40-5F	64-95
SCG	60-7F	96-127
UNL	3F	63
UNT	5F	95

Figure F-3 Command codes

D_7 D_6 D_5 D_4					X 0 0 0	Command	X 0 0 1	Command	X 0 1 0	Primary Address	X 0 1 1	Primary Address	X 1 0 0	Primary Address	X 1 0 1	Primary Address	X 1 1 0		X 1 1 1	
Bits	D_3 ↓	D_2 ↓	D_1 ↓	D_0 ↓	Column → Row ↓	0 (A)	0 (B)	1 (A)	1 (B)	2 (A)	2 (B)	3 (A)	3 (B)	4 (A)	4 (B)	5 (A)	5 (B)	6 (A)	6 (B)	7 (A)	7 (B)
	0	0	0	0	0	NUL		DLE		SP	0	0	16	@	0	P	16			p	
	0	0	0	1	1	SOH	GTL	DC1	LLO	!	1	1	17	A	1	Q	17	a		q	
	0	0	1	0	2	STX		DC2		"	2	2	18	B	2	R	18	b		r	
	0	0	1	1	3	ETX		DC3		#	3	3	19	C	3	S	19	c		s	
	0	1	0	0	4	EOT	SDC	DC4	DCL	$	4	4	20	D	4	T	20	d		t	
	0	1	0	1	5	ENQ	PPC*	NAK	PPU*	%	5	5	21	E	5	U	21	e		u	
	0	1	1	0	6	ACK		SYN		&	6	6	22	F	6	V	22	f		v	
	0	1	1	1	7	BEL		ETB		'	7	7	23	G	7	W	23	g		w	
	1	0	0	0	8	BS	GET	CAN	SPE	(	8	8	24	H	8	X	24	h		x	
	1	0	0	1	9	HT	TCT*	EM	SPD	)	9	9	25	I	9	Y	25	i		y	
	1	0	1	0	10	LF		SUB		•	10	:	26	J	10	Z	26	j		z	
	1	0	1	1	11	VT		ESC		+	11	;	27	K	11	[	27	k		{	
	1	1	0	0	12	FF		FS		,	12	<	28	L	12	\	28	l		:	
	1	1	0	1	13	CR		GS			13	=	29	M	13	]	29	m		}	
	1	1	1	0	14	SO		RS		.	14	>	30	N	14	^	30	n		≅	
	1	1	1	1	15	SI		US		/	15	?	UNL	O	15	—	UNT	o		DEL	

ADDRESSED COMMAND GROUP (ACG)

UNIVERSAL COMMAND GROUP (UCG)

LISTEN ADDRESS GROUP (LAG)

TALK ADDRESS GROUP (TAG)

PROMARY COMMAND GROUP (PCG)

SECONDARY COMMAND GROUP (SDC)

*PPC (PARALLEL POLL CONFIGURE) PPU (PARALLEL POLL UNCONFIGURE), and TCT (TAKE CONTROL) not implemented by Model 2420.
Note: D_0 = D101 ...D_7 = D108; X = Don't Care.

Typical command sequences

For the various multiline commands, a specific bus sequence must take place to properly send the command. In particular, the correct listen address must be sent to the instrument before it will respond to addressed commands. Table F-3 lists a typical bus sequence for sending the addressed multiline commands. In this instance, the SDC command is being sent to the instrument. UNL is generally sent as part of the sequence to ensure that no other active listeners are present. Note that ATN is true for both the listen command and the SDC command byte itself.

Table F-3
Typical addressed command sequence

Step	Command	ATN state	Data bus		
			ASCII	Hex	Decimal
1	UNL	Set low	?	3F	63
2	LAG*	Stays low	8	38	56
3	SDC	Stays low	EOT	04	4
4		Returns high			

*Assumes primary address = 24.

Table F-4 gives a typical common command sequence. In this instance, ATN is true while the instrument is being addressed, but it is set high while sending the common command string.

Table F-4
Typical addressed command sequence

Step	Command	ATN state	Data bus		
			ASCII	Hex	Decimal
1	UNL	Set low	?	3F	63
2	LAG*	Stays low	8	38	56
3	Data	Set high	*	2A	42
4	Data	Stays high	R	52	82
5	Data	Stays high	S	53	83
6	Data	Stays high	T	54	84

*Assumes primary address = 24.

IEEE command groups

Command groups supported by the Model 2420 are listed in Table F-5. Common commands and SCPI commands are not included in this list.

Table F-5
IEEE command groups

HANDSHAKE COMMAND GROUP	
	NDAC = NOT DATA ACCEPTED
	NRFD = NOT READY FOR DATA
	DAV = DATA VALID
UNIVERSAL COMMAND GROUP	
	ATN = ATTENTION
	DCL = DEVICE CLEAR
	IFC = INTERFACE CLEAR
	REN = REMOTE ENABLE
	SPD = SERIAL POLL DISABLE
	SPE = SERIAL POLL ENABLE
ADDRESS COMMAND GROUP	
LISTEN	LAG = LISTEN ADDRESS GROUP
	MLA = MY LISTEN ADDRESS
	UNL = UNLISTEN
TALK	TAG = TALK ADDRESS GROUP
	MTA = MY TALK ADDRESS
	UNT = UNTALK
	OTA = OTHER TALK ADDRESS
ADDRESSED COMMAND GROUP	
	ACG = ADDRESSED COMMAND GROUP
	GTL = GO TO LOCAL
	SDC = SELECTIVE DEVICE CLEAR
STATUS COMMAND GROUP	
	RQS = REQUEST SERVICE
	SRQ = SERIAL POLL REQUEST
	STB = STATUS BYTE
	EOI = END

Interface function codes

The interface function codes, which are part of the IEEE-488 standards, define an instrument's ability to support various interface functions and should not be confused with programming commands found elsewhere in this manual. The interface function codes for the Model 2420 are listed in Table F-6. The codes define Model 2420 capabilities as follows:

Table F-6
Model 2420 interface function codes

Code	Interface function
SH1	Source Handshake capability
AH1	Acceptor Handshake capability
T5	Talker (basic talker, talk-only, serial poll, unaddressed to talk on LAG)
L4	Listener (basic listener, unaddressed to listen on TAG)
SR1	Service Request capability
RL1	Remote/Local capability
PP0	No Parallel Poll capability
DC1	Device Clear capability
DT1	Device Trigger capability
C0	No Controller capability
E1	Open collector bus drivers
TE0	No Extended Talker capability
LE0	No Extended Listener capability

SH (Source Handshake Function) — SH1 defines the ability of the instrument to initiate the transfer of message/data over the data bus.

AH (Acceptor Handshake Function) — AH1 defines the ability of the instrument to guarantee proper reception of message/data transmitted over the data bus.

T (Talker Function) — The ability of the instrument to send data over the bus to other devices is provided by the T function. Instrument talker capabilities (T5) exist only after the instrument has been addressed to talk.

L (Listener Function) — The ability for the instrument to receive device-dependent data over the bus from other devices is provided by the L function. Listener capabilities (L4) of the instrument exist only after it has been addressed to listen.

SR (Service Request Function) — SR1 defines the ability of the instrument to request service from the controller.

RL (Remote-Local Function) — RL1 defines the ability of the instrument to be placed in the remote or local modes.

PP (Parallel Poll Function) — The instrument does not have parallel polling capabilities (PP0).

DC (Device Clear Function) — DC1 defines the ability of the instrument to be cleared (initialized).

DT (Device Trigger Function) — DTI defines the ability of the Model 2420 to have readings triggered.

C (Controller Function) — The instrument does not have controller capabilities (C0).

TE (Extended Talker Function) — The instrument does not have extended talker capabilities (TE0).

LE (Extended Listener Function) — The instrument does not have extended listener capabilities (LE0).

E (Bus Driver Type) — The instrument has open-collector bus drivers (E1).

G
IEEE - 488 and SCPI Conformance Information

Introduction

The IEEE-488.2 standard requires specific information about how the Model 2420 implements the standard. Paragraph 4.9 of the IEEE-488.2 standard (Std 488.2-1987) lists the documentation requirements. Table F-1 provides a summary of the requirements, and provides the information or references the manual for that information. Table F-2 lists the coupled commands used by the Model 2420.

The Model 2420 complies with SCPI version 1996 .0. Tables 5-2 through 5-11 list the SCPI confirmed commands and the non-SCPI commands implemented by the Model 2420.

Table G-1
IEEE-488 documentation requirements

	Requirements	Description or reference
(1)	IEEE-488 Interface Function Codes.	See Appendix F.
(2)	Behavior of 2420 when the address is set outside the range 0-30.	Cannot enter an invalid address.
(3)	Behavior of 2420 when valid address is entered.	Address changes and bus resets.
(4)	Power-On Setup Conditions.	Determine by :SYSTem:POSetup (Section 5).
(5)	Message Exchange Options:	
(a)	Input buffer size.	256 bytes.
(b)	Queries that return more than one response message unit.	None.
(c)	Queries that generate a response when parsed.	All queries (Common Commands and SCPI).
(d)	Queries that generate a response when read.	None.
(e)	Coupled commands.	See Table G-2.
(6)	Functional elements required for SCPI commands.	Contained in SCPI command subsystems tables (see Tables 5-2 through 5-11).
(7)	Buffer size limitations for block data.	Block display messages: 32 characters max,
(8)	Syntax restrictions.	See "Programming Syntax" in Section 4.
(9)	Response syntax for every query command.	See "Programming Syntax" in Section 4.
(10)	Device-to-device message transfer that does not follow rules of the standard.	None.
(11)	Block data response size.	See "Display Subsystem" in Section 5.
(12)	Common Commands implemented by 2420.	See "Common Commands" in Section 4.
(13)	Calibration query information.	See Service Manual.
(14)	Trigger macro for *DDT.	Not applicable.

Table G-1 (cont.)
IEEE-488 documentation requirements

	Requirements	Description or reference
(15)	Macro information	Not applicable.
(16)	Response to *IDN (identification).	See "Common Commands" in Section 4.
(17)	Storage area for *PUD and *PUD?	Not applicable.
(18)	Resource description for *RDT and *RDT?	Not applicable.
(19)	Effects of *RST, *RCL and *SAV.	See "Common Commands" in Section 4.
(20)	*TST information.	See "Common Commands" in Section 4.
(21)	Status register structure.	See "Status structure" in Section 4.
(22)	Sequential or overlapped commands.	All are sequential except :INIT.
(23)	Operation complete messages.	*OPC, *OPC? and *WAI; see "Common Commands" in Section 4.

Table G-2
Coupled commands

Command	Also changes
:SENSe...:RANGe:UPPER	:SENSe...:RANGe:AUTO
:SENSe...:NPLC	NPLC for all other functions
:SOURce...:RANGe:UPPer	:SOURce...:RANGe:AUTO
:SOURce...:STARt	:SOURce...:STEP
	:SOURce...:CENTer
	:SOURce...:SPAN
:SOURce...:STOP	:SOURce...:STEP
	:SOURce...:CENTer
	:SOURce...:SPAN
:SOURce...:STEP	:SOURce...:POINts
:SOURce...:POINts	:SOURce...:STEP
:SOURce...:CENter	:SOURce...:STARt
	:SOURce...:STOP
	:SOURce...:STEP
:SOURce...:SPAN	:SOURce...:STARt
	:SOURce...:STOP
	:SOURce...:STEP
REN, GTL	See local and remote transition in "Differences: remote vs. local operation" (Section 4).
:SYSTem:MEMory:INITialize	See command description is SYSTem Subsystem.

... = Valid function command words (i.e., :VOLT:DC, :VOLT:AC, etc.)

Index

1Ω resistor characterization 2-14

A

Abort source/measure cycle 5-98
Accuracy calculations A-6Acquire readings 5-4
Acquire statistic 5-35
Address commands F-10
Addressed multiline commands F-10
Assign unit suffix 5-24
Auto ohms measurements 2-50

B

Basic circuit configurations 2-18
Basic ohms measurement procedures 2-49
Basic Source-Measure Operations 2-1
Basic source-measure procedure 2-45
Basic sweep operation C-2
Basic sweep operation program C-12
Battery charging/discharging 2-55
Baud rate 4-47
Binning systems 2-67
Buffer considerations 2-28
Bus commands F-8
Bus description F-4
Bus lines F-5
Bus management lines F-6
Byte order 5-46

C

CALCulate [1] 5-20
CALCulate [1]:DATA? D-3
CALCulate [2] 5-29
CALCulate [2]:DATA? D-3
CALCulate [3] 5-35
CALCulate [3]:DATA? D-4
Calculate subsystems 5-20
Carrying case 1-6
CHAR SET test 4-3
Clear test results 5-34
Clearing digital output 5-75
Command codes F-11
Command words 4-27
Common commands 4-34, F-11
Compliance limit 2-5
Computer hardware requirements C-11
Cooling fan 2-36
Condition registers 4-15
Configure and control buffer 5-95
Configure and control filter 5-56
Configure and control limit tests 5-30
Configure limit tests 2-72
Configure lists 5-68
Configure measurement function 5-3
Configure memory sweep 5-70
Configure output 3-25
Configure triggering 3-20
Configure voltage and current sweeps 5-64
Configure V-source and I-source 3-9
Connections 2-39
Connections to DUT 2-40
Control autozero 5-89
Control beeper 5-89
Control display 5-37
Control remote sensing 5-87
Control source output-off 5-58
Cooling fan (output off) 5-88

D

Data Bits and Parity 4-47
Data elements 5-43
Data flow 2-28, D-1
Data format 5-40
Data lines F-6
Data store 3-21
Define math expression 5-25
Define :TEXT message 5-39
Definitions A-7
Default conditions 5-86
Differences: remove vs. local operation 4-3
Digital I/O port and safety interlock 3-23
Digital output clear pattern 2-70
Digits 3-7
Display 2-36
:DISPlay subsystem 5-37

E

Edit key 2-36
Enable and read math expression result 5-28
Enable registers 4-15
Enabling/disabling offset-compensated ohms 2-52
Error messages 4-50
Error queue 5-83, 5-90
Event registers 4-15
Example programs C-11

F

Factory Defaults E-1
Feature overview 1-2
FETCh? D-3
Filter 3-4
Flow control (signal handshaking) 4-48
FORMat subsystem 5-40
Front and rear panel familiarization 2-31
Front panel aspects of GPIB operation 4-13
Front panel summary 2-31
Front/rear terminals selection 2-39

G

GPIB bus operation and reference 4-6
GPIB bus standards 4-6
GPIB bus connection 4-7
General bus commands 4-10
General Information 1-1
General program instructions C-11
General purpose probes 1-5

H

Handshake lines F-7

I

Idle and initiate 4-24
IEEE-488 and SCPI Conformance Information G-1
IEEE-488 Bus Overview F-1
IEEE command groups F-14
Initialize memory 5-88
Initiate source/measure cycle 5-98
Interlock control 5-47
Interface function codes F-15
Inspection 1-4

K

KEYS

L

Limit testing 2-63
Limits testing program C-14
Local to remote transition 4-3
Low thermal probes 1-5

M

Main menu 3-27
Manual addenda 1-3
Manual ohms measurements 2-51
Math (FCTN) operations 2-74
Measure only (V or I) 2-53
Measurement accuracy A-6
Measurement configuration 3-3
Message exchange protocol 4-33

N

Null fee reading 5-29

O

Offset-compensated Ω 2-52, 2-74
Offset-compensated ohms procedure 2-53
Options and accessories 1-5
Operation enhancements (remote operation) 4-3
Operation overview 2-4, 2-64
Output off states 3-25, 5-47
OUTPut subsystem 5-47
Overheating protection 2-10
Overheating prevention power equations 2-10
Operating boundaries 2-11
Operating Examples C-1

P

Pass/fail testing C-6
Pass/fail test programming steps C-7
Percent deviation 2-75
Perform sweep 2-62
Perform limit tests 2-73
Power 2-74
Primary address 4-8
Program event enable registers 5-80
Program messages 4-30
Program trigger model 5-98
Programming steps C-10
Programming syntax 4-27

Q

QuickBASIC 4.5 programming 4-9
Queues 4-19

R

Rack mount kits 1-6
Range 3-3
RE-232 interface 5-94
Read and clear buffer 5-95
Read CALC2 5-30
Read condition registers 5-82
Read display 5-38
Read event registers 5-77
Read version of SCPI standard 5-93
Rear panel summary 2-31
Recalling readings 3-21
Recommended calibration equipment 2-13
Reference tables 5-6
Relative 3-6
Remote to local transition 4-4
Reset timestamp 5-88
Resistor voltage coefficient test example C-9
Response messages 4-32
:ROUTe subsystem 5-49
RS-232 connections 4-49
RS-232 operation 4-27
Rules to navigate menus 2-38

S

Safety symbols and terms 1-3
SCPI commands F-11
SCPI Command Reference 5-1
SCPI command subsystems 5-6
SCPI signal measurement commands 5-3
Select amplitude for fixed source 5-61
Select default conditions 5-83
Select function mode 5-58
Select guard mode 5-87
Select input jacks 5-49, 5-86
Select input path 5-29
Select measurement functions 5-50
Select measurement range 5-51
Select power line frequency setting 5-90
Select range 5-59
Select sourcing mode 5-59
Select statistic 5-35
Select timestamp format 5-97
Selecting ohms measurement method 2-49
Selecting an interface 4-4
Selecting and enabling math expression 2-76
Sending and receiving data 4-47
Sense and guard selections 2-44
SENSe1 subsystem 5-50
Set compliance limit 5-55
Set delay 5-63
Setting digital output 5-75
Set measurement speed 5-56Sink operation 2-54
Set voltage limit 5-62
Simulate key presses 5-92
Software requirements C-11
Source accuracy A-6
SOURce[1] 5-58
Source-Delay Measure (SDM) cycle timing A-7
SOURce subsystem 5-58
Source-measure concepts 2-4
Specifications 1-3
Speed 3-8
Status and error messages 2-37, B-1
Status Byte and Service Request (SRQ) 4-23
Status register format 5-46
Status structure 4-15
Status subsystem 5-77
Storing readings 3-21
Sweep and list program examples 5-72
Sweep operation 2-56
Sweep types 2-56
Select and configure sweep 2-61
Set delay 2-62
SOURce2 5-74
Source configuration 3-9
Source-Measure Options 3-1
Specifications A-1
SRQ on IDLE C-5
SRQ on MAV C-5
SRQ on OPC C-5
SRQ on sweep done C-5
:SYSTem subsystem 5-86
Sweep operation programming steps C-3
Sweep test example C-2

T

Terminator 4-48
Test fixture interlock 2-39
:TRACeDATA? D-3
:TRACe subsystem 5-95
Trigger link 3-15
Trigger model 3-10
Trigger model (remote operation) 4-23
Trigger model operation 4-24
Trigger operations 3-10
Trigger subsystem 5-98
Troubleshooting 4-1
Toggle key 2-37
Turn source on or off 5-47
Typical command sequences F-13

U

Unaddress commands F-10
Uniline commands F-9
Universal multiline commands F-9
Universal program fragments 4-9
Using program fragments 4-9

V

Varistor alpha 2-75
Voltage coefficient 2-75
Voltage coefficient test program C-15

W

Warranty information 1-3
Warning-Caution 2-3

Service Form

Model No. _____ **Serial No.** _____ **Date** _____

Name and Telephone No. _____

Company _____

List all control settings, describe problem and check boxes that apply to problem. _____

_____

_____

❑ Intermittent ❑ Analog output follows display ❑ Particular range or function bad; specify

_____

❑ IEEE failure ❑ Obvious problem on power-up ❑ Batteries and fuses are OK

❑ Front panel operational ❑ All ranges or functions are bad ❑ Checked all cables

Display or output (check one)

❑ Drifts ❑ Unable to zero ❑ Unstable

❑ Overload ❑ Will not read applied input

❑ Calibration only ❑ Certificate of calibration required ❑ Data required

(attach any additional sheets as necessary)

Show a block diagram of your measurement including all instruments connected (whether power is turned on or not). Also, describe signal source.

Where is the measurement being performed? (factory, controlled laboratory, out-of-doors, etc.)_____

_____

What power line voltage is used? _____ Ambient temperature? _____ °F

Relative humidity? _____ Other? _____

Any additional information. (If special modifications have been made by the user, please describe.)

_____

_____

Be sure to include your name and phone number on this service form.

KEITHLEY

Keithley Instruments, Inc.
28775 Aurora Road
Cleveland, Ohio 44139

Printed in the U.S.A.